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Shielding Against Gamma Rays, Neutrons, and Electrons From Nuclear Weapons

A Review and Bibliography

J. H. Hubbell and L. V. Spencer

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Shielding Against Gamma Rays, Neutrons, and Electrons From Nuclear Weapons. A Review and Bibliography

J. H. Hubbell and L. V. Spencer

The problem of predicting dose rates and of estimating the effectiveness of shielding from radiations resulting from nuclear explosions is discussed. A number of existing calculations and supporting experiments regarding the penetration and diffusion of gamma rays, neutrons, and electrons through air and bulk materials are summarized. Indications are given of gaps in such input information. A selection of 485 references from the unclassified literature is presented, of which 388 are cataloged as to source geometry and energy, absorber material and configuration, type of data presented, and method of calculation or experimental technique. These cataloged references include radiation field studies ranging from the point-source infinite-medium situation up through such complicated geometries as foxholes, shelters, and conventional structures. The other references are of a general or review nature or contain input spectral data.

I. Preliminary Statement

The problem of shielding against radiation due to nuclear weapons involves estimation of the radiation dose in an arbitrary configuration of radiation sources and shielding materials. In making such estimates, data for *simple* structure types have been very useful. This is because a complicated structure can often be schematized as a combination of simple structures. From our point of view, the infinite, homogeneous medium, i.e., the total lack of structure, may be considered the simplest case, as well as the most useful. In NBS Monograph 42 [G1],* gamma-ray data generated for infinite, homogeneous media are presented in engineering-type graphs; and the use of these data in analyzing many elementary structure types is discussed. A more complete engineering methodology, for analyzing complicated as well as simple structures, is given in a parallel series of OCD reports [G46, G47].

This Monograph is primarily a catalog and bibliography of experiments and calculations relating to simple configurations, including the infinite, homogeneous medium. It extends the documentation of [G1] and indicates the availability of data, calculations, and corroborative experiments for neutrons as well as gamma rays.

The next few sections of this introduction are designed to introduce the configurations considered "elementary," the types of data which have been the object of research efforts, and some types of data which have been omitted or only partially included here. The gamma-ray reports constitute the largest single group listed, with neutron reports second. For completeness, reports on electron penetration have also been included.

We have tried to include all unclassified reports and publications which have seemed directly pertinent to the basic problems of weapons shielding, and which involve elementary configurations. At the same time, we are quite certain that we have missed reports, some very important; and we would greatly appreciate having our attention called to such oversights.

*References on pages 22–33.

II. Comparison of Different Approaches

The use of data for elementary configurations is only one approach to the study of radiation shielding problems. A second approach utilizes mockups of interesting configurations in the vicinity of test explosions. This "field test" type of experiment provides a direct answer to a specific shielding question even in very complicated cases. By performing a large variety of field test experiments it is possible to arrive at a "feeling" for the propagation of radiation from nuclear devices. But the number of variables even in relatively simple cases is very large; and the approach is therefore not naturally extensible to new situations.

A complementary procedure is that of attempting to study small-scale mockups exposed to radiation resembling that from weapons. Experiments of this type may be performed in a laboratory relatively cheaply and easily. Beyond

these advantages, such model studies can give information on effects due to *changes* in a structure or radiation source. With models, it is much more nearly possible to arrive at an understanding of radiation effects through a single type of experimentation. It is unfortunate that the model approach has seemed to be unsuited to the study of shielding against neutrons.

All of these methods reinforce and complement one another in different ways, since each is appropriate to specific types of shielding questions. But, it has been advantageous to turn even field tests and model studies to the investigation of particularly important examples of elementary configurations; and a number of research papers describing such work are given.

III. Types of Information

Figure 1 gives a block diagram of the types of information required for the interpretation of radiation effects from nuclear weapons. In brief, the top row of blocks identifies the radiations generated in the elementary nuclear reactions. In the second row of blocks, these different types of radiation are divided into two groups, initial and delayed radiations. It should be noted at this point that the spectra which correspond to the elementary reactions (top row) will be modified by weapon design and its location at detonation. Thus, the spectra of "initial" and "delayed" radiations will not be a simple superposition of spectra for the elementary reactions.

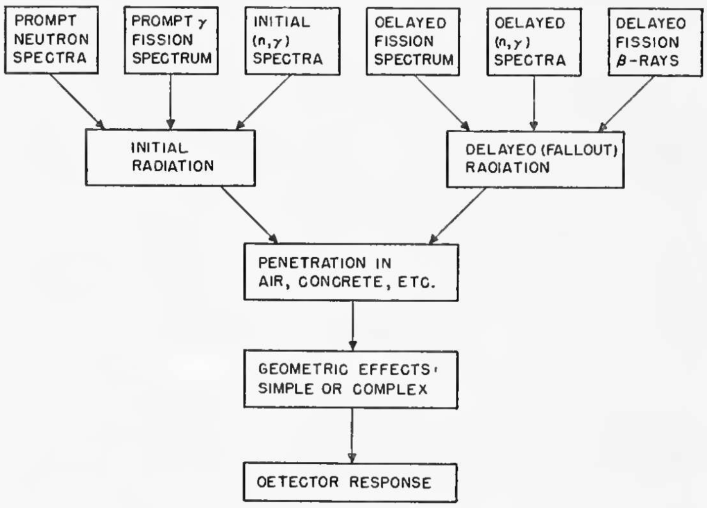

FIGURE 1. *Types of information required for the analysis of local radiation intensities resulting from nuclear weapons.*

Both initial and delayed radiations penetrate air, earth, and other materials. This penetration is affected by the geometry of the source and by the configuration of the absorbers. The third and fourth rows on the diagram of figure 1 stand for information of this type.

Lastly, the detector determines the radiation characteristics which are measured. The detector response can be viewed as a parameter characterizing the spectrum. It is usually convenient to agree on standard types of detector response and in this way subordinate the discussion of the radiation spectrum to other features of the problem.

Source spectra, penetration, and geometry information are all necessary for a reasonably complete understanding of radiation effects and an ability to make predictions for new configurations. Much spectral information, particularly that indicated by the second row in the diagram, is classified because one can deduce from it certain things about the design of a weapon. This does not decrease its basic importance in shielding problems, and one way or another it must be taken into account. Here we omit all such information. The gaps which result have the nature of missing multiplicative constants and do not necessarily result in a misleading picture of the current status. Further, it is possible to perform calculations or experiments for individual components which may appear in the spectra, and to make a superposition at a later time when data on source strengths are available.

IV. Basic Spectral Components

While we do not attempt to catalog the large body of reports dealing with the spectra of specific source components, a few comments about the state of information on the main components follow.

A. Initial Radiations

Proceeding from left to right along the top row of figure 1, we consider first the *initial radiations*. Neutrons are produced in great abundance, two or more from a fissioning nucleus. Neutrons also result from fusion reactions. The spectrum from fast neutron fission has been determined, and is given by the solid curve in figure 2 [SD22]. The spectrum from individual fusion reactions is known although one does not know relative strengths. The dashed lines in figure 2 represent several fusion neutron spectral energies [G20]. In general, fusion neutrons are higher in energy and correspondingly tend to be more penetrating than fission neutrons.

The prompt fission gamma spectrum is reasonably well known. The curve in figure 3 is from an experiment by Francis and Gamble [SD10] in which gamma photons were detected in coincidence with fission fragments in a fission chamber.

The penetration of initial gamma rays is likely to be influenced by neutron capture in nitrogen of the air, since this reaction produces very high energy gamma rays [SD12], as indicated by the

dashed lines in figure 3. These capture gamma rays are not only more penetrating than the fission gamma rays, but they also start from locations determined by the penetration of neutrons. Thus, they "ride piggy-back on the neutrons" for part of their way. Other (n, γ) reactions must contribute to the initial radiation, but those of figure 3 may well be the most important because of their penetrability and also because of a substantial cross section for the capture process.[1]

B. Delayed Radiations

Next we turn to the *delayed radiations*. The fallout spectrum is produced by superposition of spectra from reactions having many differing half-lives. Correspondingly, the spectrum may change drastically as a function of time after the detonation, and it is necessary to determine spectra either for time intervals or for particular times of interest. Since the spectrum from a pile corresponds to a very long time interval, whereas the times and time intervals for shielding against fallout radiation are relatively short, pile research makes only a limited contribution to our information about this component.

There has been an increasing body of data on delayed gamma rays from fission. Most of this information comes from calculations of the yield of different nuclear species as a function time after fission. In figure 4, spectra obtained by Björnerstedt [SD2] in this way is given. Experimental information is available on spectra corresponding both to short and long times after fission, and an example of this type of data is given in figure 5 [SD25].

[1] F. Ajzenberg and T. Lauritsen, Rev. Mod. Phys. **27**, 77 (1955).

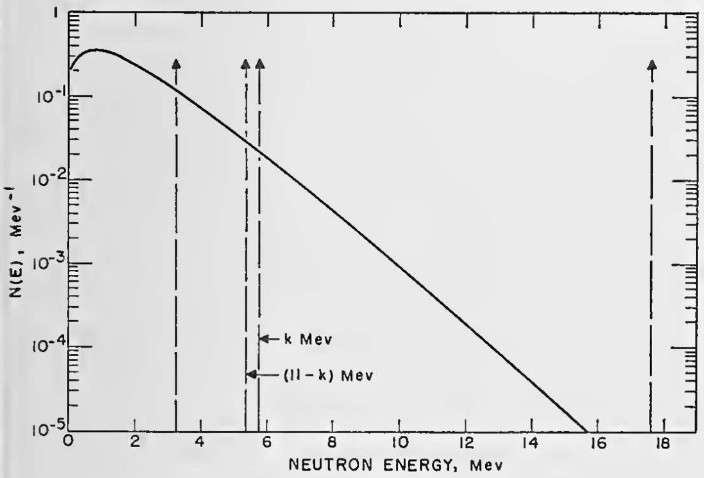

FIGURE 2. *Watt fission neutron spectrum SD 22 (curve) and principal fusion neutron energies G 20 (dashed lines).*

k Mev, 11-*k* Mev dashed lines represent the neutron pair from the fusion reaction: $H^3+H^3=He^4+2n+11$ Mev, in reality a continuum with a maximum energy of 11 Mev. The other dashed lines represent maximum neutron energies from the reactions $H^2+H^2=H^3+n+3.2$ Mev and $H^3+H^2=$ $e^4+n+17.6$ Mev.

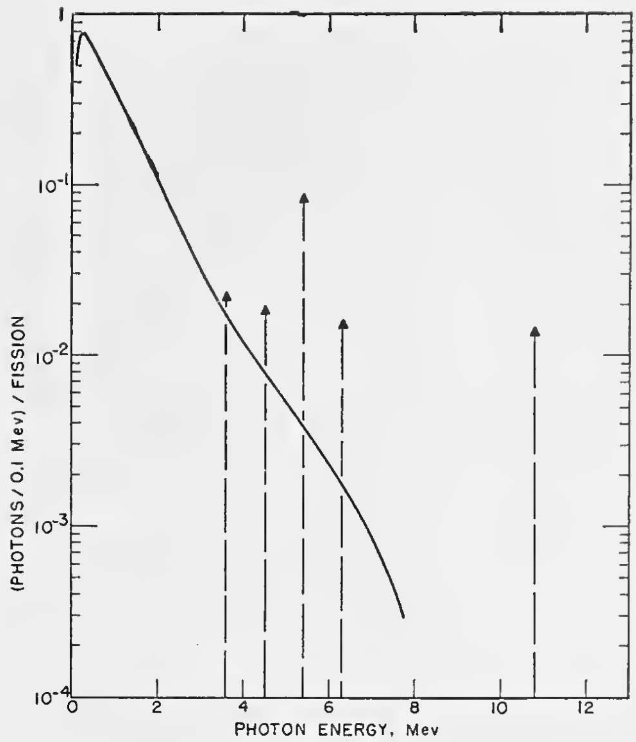

FIGURE 3. *Fission prompt gamma spectrum SD 10 (curve) and nitrogen neutron-capture gamma-ray energies SD 12 (dashed lines).*

The ordinates relate the gamma photon counts to the fission fragment counts gating the photon detector. The dashed nitrogen lines have been drawn at arbitrary heights roughly indicating relative intensities.

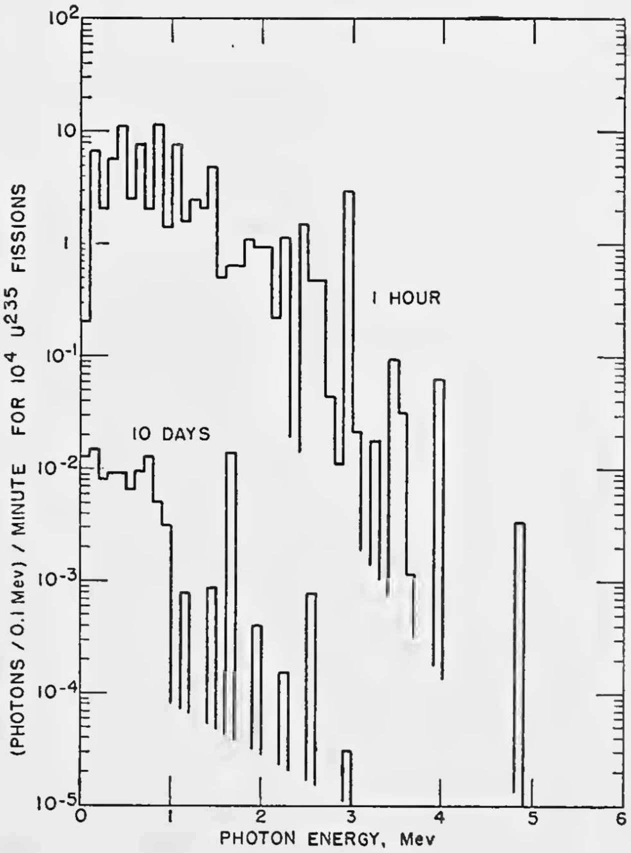

FIGURE 4. *Calculated gamma-ray spectra of fission products at various times following fission resulting from U-235 slow-neutron capture, based on data in reference [SD 2].*

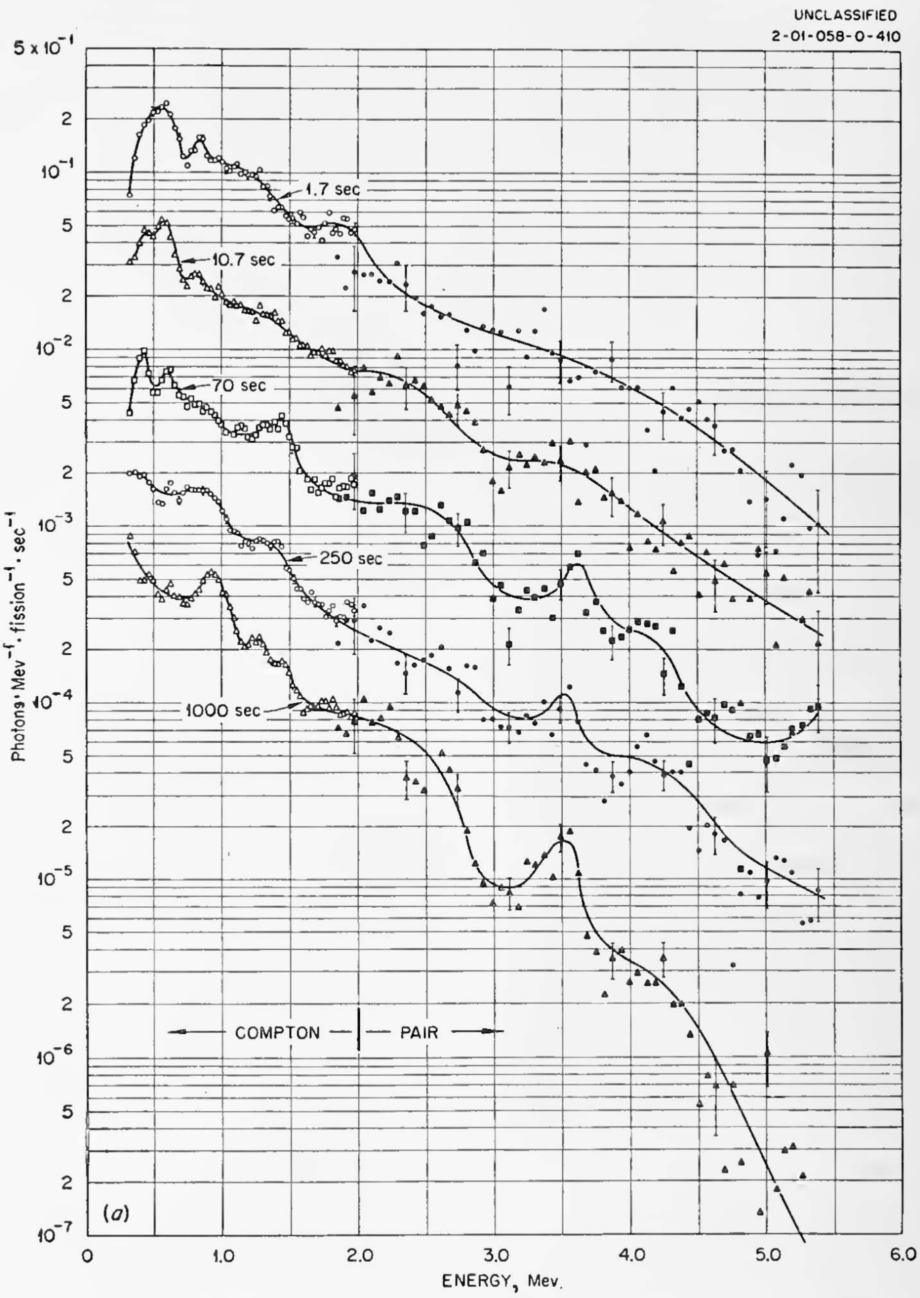

FIGURE 5. *Fission-product gamma-ray spectra measured at short times after U–235 sample irradiation, using Compton and pair spectrometers [SD 25].*

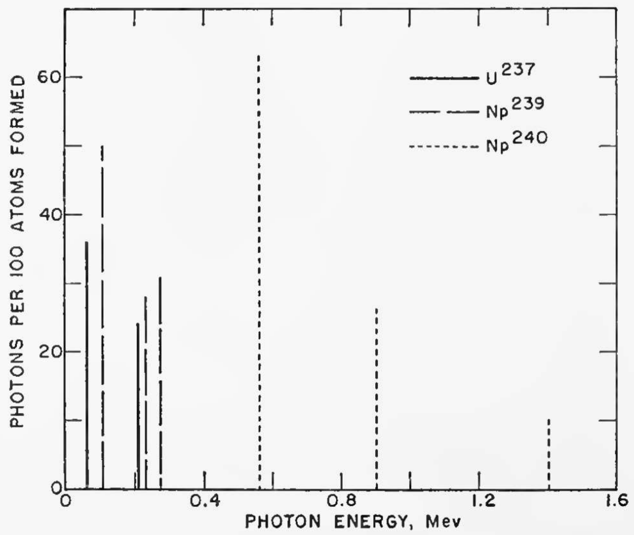

FIGURE 6. *Gamma-ray energies from neutron capture in U–237, Np–239 and Np–240.*

It should be remembered that spectra from two different fissioning atoms will differ from one another, and also that spectra from slow-neutron fission will differ from spectra corresponding to fast-neutron fission. But to date, the evidence suggests that penetration differences which result from differing spectra are minor [G1].

Several types of (n, γ) reactions have importance for delayed (fallout) spectra. Figure 6 gives some of the gamma-ray energies which result from neutron capture in uranium or neptunium. Note that they are mostly rather low in energy. Mather [SD15] has published sample pulse-height distributions for fallout which clearly show the 2.8 Mev component of Na^{24} produced by neutron capture in the ground, the 1.6 Mev gamma rays from La^{140}, and the longer-lived 0.75 Mev activities of the Zr^{95}–Nb^{95} decay chain. The possibility of introducing other contaminant materials into the detonation has been given some publicity,

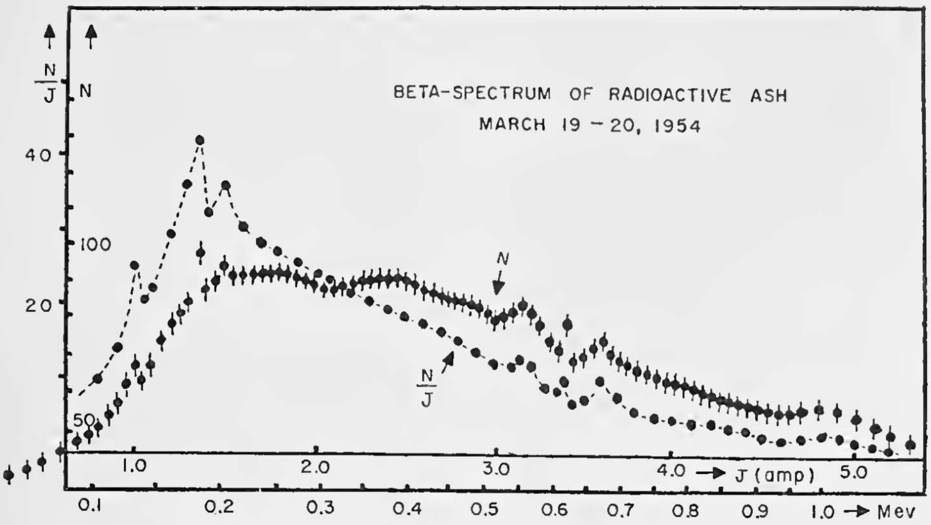

FIGURE 7. *Fission-product beta-spectrum (about 20 days following the detonation).*

The skewered-dot curve, *N*, is the number spectrum, or beta particles per unit energy interval. The dashed-connected curve, *N/J*, has been divided by momentum for Fermi-plot analysis.

but there is very little unclassified information available on the subject.

Next, we consider the delayed beta rays from fission. While these particles are not very penetrating (see fig. 9), they have produced serious burns in the case of the Marshallese Islanders; and they represent a hazard also through ingestion into the body with food, water, or air. Figure 7 gives some of the (rare) data on the gross fission beta spectrum. It was measured by the Japanese several weeks after contamination of the Lucky Dragon.[2]

C. Effects Which Modify Initial and Delayed Intensities and Spectra

It is possible to describe qualitatively some of the spectral characteristics which are determined by the detonation geometry; but quantitative information is, of course, classified.

For example, a bomb cannot fly apart with anything like the speed of light because of equipartition of energy and the considerable atomic mass of the constituent elements.[3] But the prompt gammas and high energy prompt neutrons travel essentially with the speed of light. They must therefore penetrate the outer layer of bomb material and subsequently the air prior to other disturbances. The intensity of the prompt radiation emerging into the air will therefore be lowered and the spectrum of both gammas and neutrons will be altered. Fortunately, however, neutron and gamma-ray spectra are often rather insensitive to penetration. Because of this, the continuous nature of the spectra, and the greater penetrability of high energy components, such spectral modifications are not likely to dominate the penetration through air and shield. The main effect of the weapon geometry is thus the introduction of unknown multiplicative constants.

Subsequent phenomena include the removal of the air from an enormous volume about the initial detonation, with corresponding high compression of the air at the air-vacuum interface. This modification of absorber geometry does not change spectra or angular distributions very much; but it may affect the air attenuation considerably while this "shell" configuration persists. Note that prior to the passage of the compression wave the number of mean free paths of air protecting a detector location decreases due to concentration in the shell, while after passage of the compression wave there may be a decrease due to removal of air to positions beyond the detector.

The fallout spectra produced by fission products should be similar to the theoretical gamma-ray and beta-ray spectra from fission. But one hardly expects to see contributions from volatile materials, such as the rare gases, which may occur among the fission products. These materials should remain in the atmosphere. Other modifications may result from differences with time in the chemical and physical behavior of fission product elements; and the magnitude and nature of these modifications are extraordinarily difficult to estimate. The generic term "fractionation" is used for these effects.

Finally, we might simply note that the source strengths of both prompt and delayed (n, γ) radiations from air, earth, or bomb constituent materials are a function of the type of detonation and its location.

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[2] Y. Nishiwaki, T. Azuma, et al., Research in the effects and influence of the nuclear bomb test explosions, Vol. 1, p. 464; Publ. by Jap. Soc. for Promotion of Sci., Ueno, Tokyo (1956).

[3] For an unclassified description of the kinetics of an atomic explosion, see ref. [G20].

V. Radiation Penetration in the Absence of Boundaries

Particular interest attaches to the study of penetration in the absence of boundaries, as already mentioned, this being the case most amenable to detailed theoretical study. For a given source strength $S(r,E)$ of gamma rays, neutrons, or beta rays, emitting energy E at location r, in a medium without boundaries, a variety of data types can be determined, some of which are indicated in figure 8. Proceeding from left to right, we may wish to know simply an integral which can be generically termed the "dose." We may wish to know how different spectral components contribute to the "dose." Or, we may wish to know from which directions the "dose" is delivered. (Directional information may be put in integral form, and may be referred to as "geometry factor" data. Similarly, "barrier factor" data refer to "dose.")

The last item in figure 8 refers to the amount and kind of radiation reflected from a surface, and this implies a boundary.

Extensive investigations of these quantities have been made. Tables 1 to 4 outline much of the available literature for gamma rays and neutrons. Note that although our comments pertain mostly to point isotropic (PTI) sources, other source configurations are also important. For example, data on plane isotropic (PLI), plane slant (PLS), and other source geometries have proved useful and have been determined experimentally or theoretically.

In general, the study of neutron penetration is more difficult than the study of gamma-ray penetration because the cross sections are less well known and more irregular, and because detection presents more of a problem. The number of elements whose cross sections are known completely enough to permit a fairly reliable theoretical analysis is still small. Further, measurement of neutron intensities is far easier than measurement of spectra or directional distributions. These things contribute to the generally less satisfactory status of neutron penetration data.

The study of beta-ray penetration from fission products is still in its infancy, partly because the shielding problem appears to be easily soluble. Nevertheless, information of this type has its applications. Figure 9 gives results from the one theoretical fallout beta study available at the moment [ET5]. Tables 5 and 6 summarize the literature.

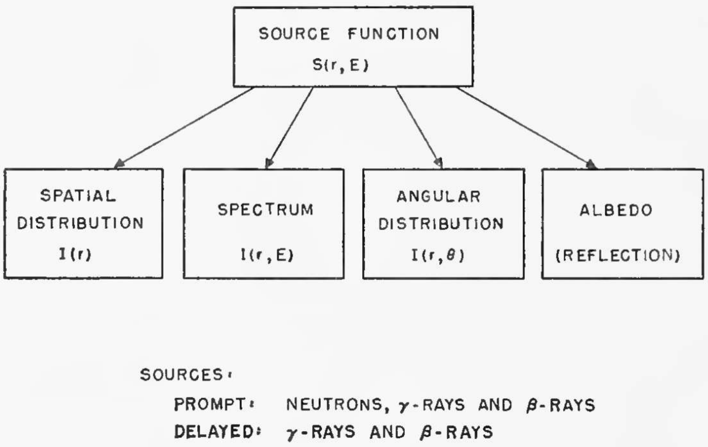

Figure 8. *Types of information describing the radiation field.*

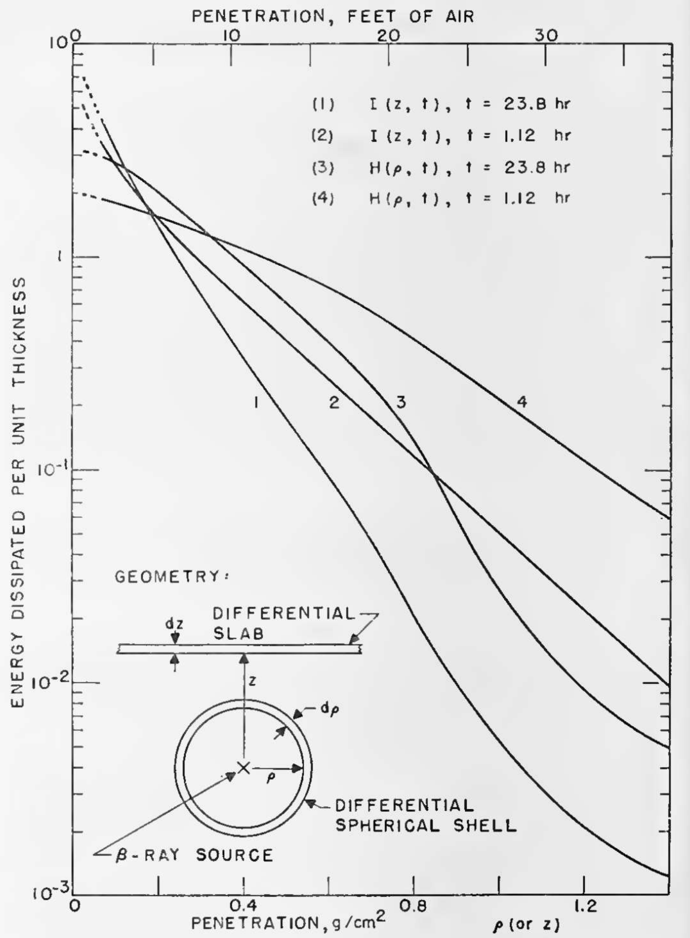

Figure 9. *Energy dissipation in a differential slab at distance z from a point beta-ray source (curves 1 and 2) and in a differential spherical shell at radius ρ from the source (curves 3 and 4).*

These curves, based on beta spectra 1.12 hr and 23.8 hr after U-235 slow neutron fission, are from reference [ET 5].

VI. Elementary Configurations With Boundaries

Most of the studies in tables 1 to 4 are either theoretical analyses or descriptions of laboratory experiments, but the field tests have made contributions also. In figure 11 are data on the penetration of fallout gamma rays into concrete, as determined by measurements on one of the test shots in Nevada [GE54]. The experiment is diagramed in figure 10. Unfortunately, lack of unclassified information about the device limits our possibility of analyzing this data theoretically.

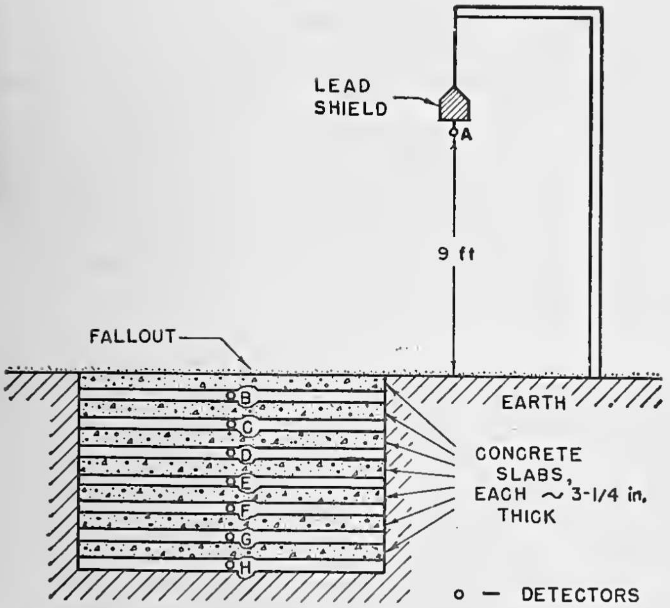

FIGURE 10. *Schema of the layout used for measuring penetration and time-decay of actual test-shot fallout material (see fig. 11).*

The lead shield prevents fallout material from settling directly on detector "A," while at the same time shielding against the intercepted material (ref. [GE 54]).

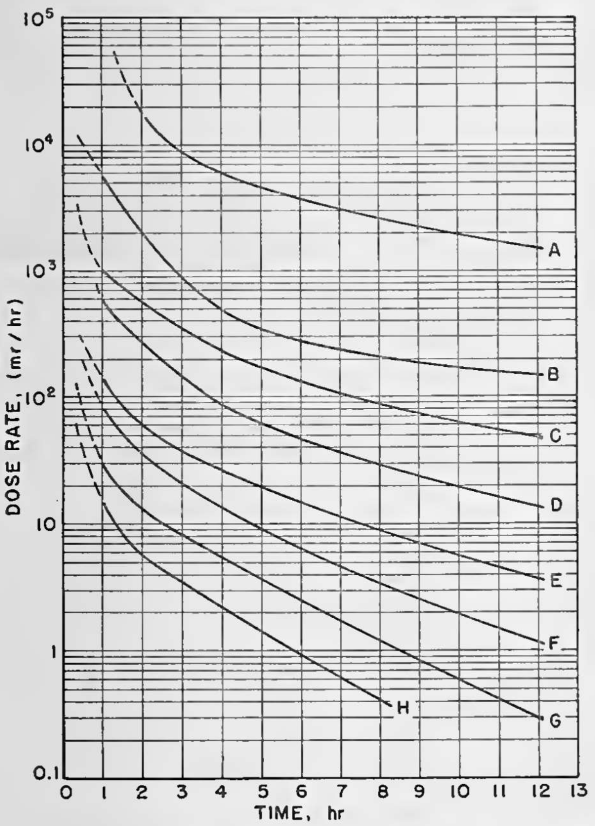

FIGURE 11. *Dose rates from test-shot "Shasta" as a function of time, measured by detectors located as indicated in figure 10.*

Intensities at $T<1$ hr exceeded the ranges of the detectors, and should be disregarded (ref. [GE 54]).

The best summary of field test penetration data is still contained in the Effects of Nuclear Weapons [G20]. This summary, unfortunately, is not documented with references to specific sources of data, but references to several other summaries are included in the 1962 revision, as well as lists of publications by the OCDM and by the USAEC, Civil Effects Test Operations.

In figure 12 a number of elementary absorber configurations are sketched. Note that more complicated structures contain different combinations of those pictured. For example, an underground shelter can be considered as a combination of *shielded foxhole* with a *maze* entrance and possibly a maze ventilation system. Correspondingly, an above-ground shelter might be a *blockhouse*.[4] This combines a *vertical wall*, possibly *vents* in the walls, and an overhead slab which shields in the same manner as in the case of the *shielded basement* or *foxhole*. The *foxhole* (unshielded) is self-explanatory. Most frame houses are simple *light superstructures*. A large apartment building would perhaps combine a *blockhouse*, with *vertical walls*, *compartmentation*, *vents*, and *in-and-down* configurations. To complete our list in figure 12, we might note that the air-ground *density interface* plays an important role in structure shielding.

Tables 7 to 9 give studies of these elementary geometries. The special topic of mazes, or ducts, has been treated separately because of the attention which it has received.

Note that neutron penetration data for elementary configurations are still scarce, that many of the papers on these topics are recent, and that some configurations have as yet received little attention. These configurations may not be as well chosen for neutrons as for gamma rays.

[4] The term "blockhouse" is used generically, as are all these designations. We do not imply a limitation to a particular shape.

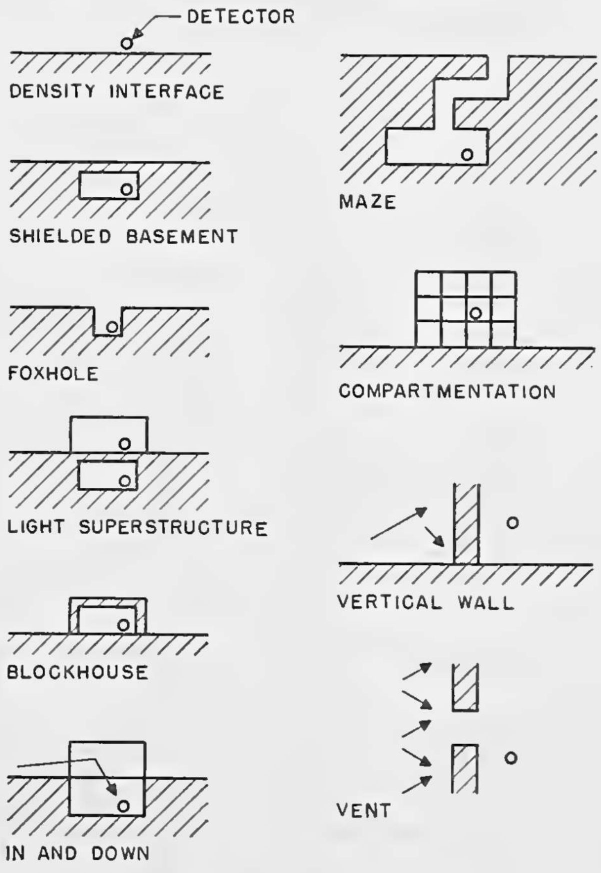

FIGURE 12. *Simple geometries.*

VII. Experiments and Calculations for Structures

A table of experiments and calculations for existing buildings and other structures has been included (table 10). Here the elementary configuration data are applied and tested. There exist measurements and calculations for light structures, below-ground shelters, and large, fairly regular structures. It should be noted that the analysis of the experimental data on mazes is most extensive.

Another reservoir of structure data is the Federal Shelter Survey [G47]. Presumably, analyses of these data will be made in the future. Results of the Survey calculations can be obtained; but these calculations were not very sophisticated.

VIII. Final Comments

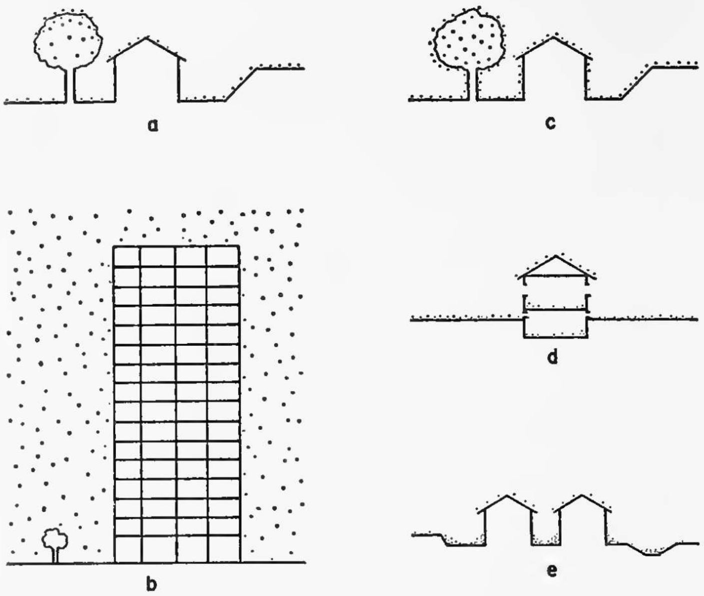

FIGURE 13. *Fallout source types.*

a Uniform surface distribution on exposed horizontal projections.
b Volume source, describing a descending cloud of radioactive particles.
c All surfaces uniformly contaminated.
d Fallout material entering structures.
e Accumulation of fallout material in particular areas as a result of rain run-off, drifting, etc.

We might note that more than one source configuration of potential importance had been very little explored. For example, only a few papers exist which deal with the enveloping cloud of fallout; and hardly any work has been done for a uniform distribution of fallout over all exposed surfaces. Both cases, and others which might be relevant at different times in different weather conditions, are illustrated in the sketches of figure 13.

The most concentrated effort of the near future is likely to be in the area of neutron penetration. Both calculations and experiments for a number of elementary configurations are in progress.

There is apt to be more on electron penetration in the future, not because of shielding against nuclear explosions, but because of space vehicle shielding problems which have recently come to attention.

The authors thank C. S. Cook, H. J. Tiller, and D. K. Trubey for reviews and comments on the manuscript, and M. J. Berger for a number of suggestions as to organization and presentation of the cataloged reference material.

TABLE 1. *Gamma-ray penetration theory (GT)* *

Ref.	Author	Yr	Lab. or [place]	Source energy, Mev	Source type	Medium	Absorber configuration	Type of information	Method
GT1	Akkerman, Kaipov	61	[USSR]	0.66	PLN	Al	FS	*T, R, BF*	MC.
GT2	Auslender	57	ORNL	1, 3, 6	PLN, PLS (60°)	Pb, H_2O	FS, Lay	*I(r), BF*	MC.
GT3	Berger	55	NBS	1.0	PLI	H_2O	IM	$I(E, r, \theta)$	MM.
GT4	Berger	55	NBS	0.66	PLN, PLS	H_2O	IM, SIM, FS	*T, R*	MC: CD, AA.
GT5	Berger	56	NBS	0.66	PLS	H_2O	IM	*I(r)*	MM.
GT6	Berger	57	NBS	1.28	PTI	H_2O, Air	2 media with interface	*I(r, h)*	MC: CD, AA.
GT7	Berger, Doggett	56	NBS	0.66, 1.0, 4, 10	PLN	H_2O, Fe, Sn, Pb	IM, SIM	*T, R*	MC: AA, analyt. calc. of displacements.
GT8	Berger, Raso	60	NBS; TOI	0.02–2.0	PLS, PLI	H, H_2O, Concrete, Fe, Sn, Pb	SIM	$R(E, \theta)$	MC.
GT9	Berger, Spencer	59	NBS	1.28	PTI, PMD	H_2O	SIM, Sph	*I(r)*	MC: CD, AA.
GT10	Berger, Spencer	59	NBS	0.0341–10.22	PTI, PLI	Al, Concrete	IM	*I(r), BF*	MM.
GT11	Bruce, Johns	60	[Toronto]	0.05, 0.1, 0.2, 0.5, 1.25	PLN	Compt. Scatterer, H_2O, Al	SIM	*I(E, r)*	MC.
GT12	Burrell, Cribbs	60	[Lockheed]	0.5, 1, 2, 5, 9	PLS	Fe	FS	$I(E, r, \theta)$	MC—extensive tabulation.
GT13	Capo	58	APEX	0.4–9.5	PTI	H_2O, Al, Fe, Sn, Pb, W, U	IM	*BF* as cubic polynomial	Least-squares fit to NYO–3075 data (GT 20).
GT14	Chilton, Holoviak, Donovan	60	NCEL	0.5–10	PTI	Al	IM	2-parameter *BF*	Least-squares fit to NYO–3075 data (GT20).
GT15	Chilton, Huddleston	62	NCEL	0.2–10	PLS	Concrete	SIM	2-parameter *R*	Semi-empirical fit to GT29.
GT16	Dawson et al.	58	WADC	1.17, 1.33	PTI	Air	IM	$I(E, r, \theta)$	MC.
GT17	Donovan, Chilton	61	NCEL	Fallout spectrum	PLI	Concrete	FS	*I(r)* vs time after fission	Use of SD18 spectral data, GT10 *BF*.
GT18	Faust, Anderson	62	NRL	Unspecif. monoenergetic	PMD	Unspecif.	IM	$I(r, \theta, \varphi)$	Sph. harmon.
GT19	Gates, Eisenhauer	54	AFSWP	0.25, 1, 2, 4, 6	PTI, PLI UVD,	Air	IM	*I(E, r)*	MM.
GT20	Goldstein, Wilkins	54	NDA	0.255–10	PTI, PLN	H_2O, Al, Fe, Sn, W, Pb, U	IM	*I(r), I(E, r)*	MM—extensive tabulation.

* For key to notation, see glossary at end of tables, p. 20.

TABLE 1. *Gamma-ray penetration theory (GT)*—Continued

Ref.	Author	Yr	Lab. or [place]	Source energy, Mev	Source type	Medium	Absorber configuration	Type of information	Method
GT21	Hayward, Hubbell	55	NBS	1.0	PLN, PLI, PLS	H_2O, Al, Cu, Sn, Pb	SIM	*R*	MC: AA.
GT22	Kalos	59	NDA	1–6	PLN	Pb–H_2O	Lay	*T*	MC: IS.
GT23	Leshchinskii	60	[USSR]	Co^{60}, Cs^{137}	PTI, line	Air, H_2O, Al, Fe, Co	IM	$I(r)$, *BF*	*BF* fitted as $e^{+x}\sum_{i=0}^{N} a_i x^i$
GT24	Lynch et al.	58	ORNL	0.6–12	PMD	Air	IM	$I(E, r, \theta)$	MC.
GT25	O'Reilly	61	WAPD	1, 3, 6	PLN	H_2O, Fe, Pb	FS	$I(E, r)$	MM.
GT26	Peebles	53	RAND	0.511–10.22	PLN, PTI	Compt. scatterer, Fe, Pb.	FS	*T*, *R*	Integral recursion.
GT27	Perkins	55	NARF	0.66–6.0	PLN, PLS	Al, Concrete	SIM	*R*	MC: AA, CD.
GT28	Pullman	56	NDA	Au^{198}, Cs^{137}, Co^{60}, Na^{24}.	PLS	Al, Fe, Pb, concr., rubber, lucite, paraffin, polyethylene.	FS, Lay	*T*	Extensive collection of calc. and experimental data; graphical comparisons.
GT29	Raso	61	TOI	0.35, 0.66, 1.25; 1.12- & 23.8-hr fission products.	PLS	Concrete, Fe	FS	*T*; $D(r, \theta)$; $I(r, E)$; $I(r, \theta)$.	MC.
GT30	Raso	62	TOI	0.02–10	PLS	Concrete	SIM, FS	*T*, *R*	MC.
GT31	Serduke, Scofield, Kreger.	59	NRDL	0.66	PLN	Al	FS	$I(E, r, \theta)$	MC.
GT32	Shure	62	WAPD	1.28	PMD	H_2O	FS	$I(r, \rho)$: radial spread.	MC.
GT33	Spencer	52	NBS	5.11, 10.22	PLI, PLS	Pb, Fe	IM	$I(E, r)$	Fourier transform.
GT34	Spencer, Fano	51	NBS	1.0–10.2	PLI, PLS, PTI, PMD.	Pb	IM	$I(E, r)$	MM.
GT35	Spencer, Jenkins	49	NBS	5.1	PTI	Pb, Al	IM	$I(E, \theta)$	MM.
GT36	Spencer, Lamkin	58	NBS	0.034–10.22	PLS	H_2O	IM	$I(r)$	MM.
GT37	Spencer, Lamkin	59	NBS	0.66, 1.17, 1.33; fallout spectra; N *n*-capture γ's.	PLS	H_2O	IM	$I(r)$	MM.
GT38	Spencer, Lamkin	59	NBS	0.043–10.22	PLS	Concrete	IM	$I(r)$	MM.
GT39	Spencer, Stinson	52	NBS	1.33	PLS, PTI, PMD.	H_2O	IM	$I(E, r)$ $I(E, r, \theta)$.	MM.
GT40	Spencer, Wolff	53	NBS	1.0–10.22	PTI	H_2O	IM	$I(E, r)$, incl. polarization.	MM.
GT41	Steinberg, Aronson.	60	TRG	Bremss., E_{max}=8, 10.	PTI, PLN, PLS.	Al, Fe, Pb	FS	$I(E, r)$	MC.
GT42	Taylor	54	WAPD	0.5–10	PTI	Pb, H_2O, Fe	IM	3-parameter *BF*.	2-exponential fit to GT20.
GT43	Theus, Beach	56	NRL	6.13	PLN, PLS	Fe	SIM	*R*	MC: AA, annihil. rad. incl.
GT44	Theus et al.	54	NRL	0.66–6.0	PLN, PLS	H_2O, Pb	FS, SIM	*T*, *R*	MC: AA, IS.
GT45	Trubey	61	ORNL	0.6–12	PMD	Air	IM	$I(r,\theta)$	Single scatt. approx.
GT46	Wells	59	NARF		PTI	Air, Concrete	SIM	$I(E,\theta)$	MC.
GT47	Wilson	52	[Cornell]	20–500	PLN	Pb	IM	$I(r)$	MC: electrons and positrons followed as well as photons.
GT48	Zerby	56	ORNL	1.3	PLN PLS	Pb, Polyethylene	Lay	*T*	MC.
GT49	Anderson	58	WAPD	6.0	PLI; Line source.	H_2O, Fe, Pb	IM	*BF*	Use of GT42 data.
GT50	Anderson	58	WAPD	1.28, 5.11	PLS, PLI	Fe, Pb	IM, FS	*BF*; $I(r)$	Peeble's "orders-of-scattering" approach.
GT51	Bowman, Trubey	58	ORNL	1, 3, 6, 10	PLS, PLN	Pb, H_2O	Lay; FS	*BF*; $I(E,r,\theta)$	MC
GT52	Coppinger	61	HW	0.5–3.0	PTI	Concr., ordinary and magnetite; Pb, Fe, H_2O, Pb-glass	FS	*T*	Approx. formulas; graphs; *BF* incl.
GT53	Ermakov, Zolotukhin, Kom'shin	62	[USSR]	0.5, 1.25, 7.0	PLS	Polyethylene	FS	$I(E, r, \theta)$	MC.
GT54	Flew, James	55	AERE	Fission products: 1, 16, 63 days.	PLN	U, Pb, Fe, Al	IM	$I(r)$	Use of G17 data.
GT55	Leimdörfer	62	AE	1.0–10.0	PLN	Concrete	FS	$R(E, r)$	MC.
GT56	Leimdörfer	62	AE	1.0	PTI	Concrete	Sph. wall	$R(E)$ vs radius of curvature.	MC
GT57	Marcum	62	RAND	0.66, 1.28	PTI	Air, ground	2 media with interface	$I(r, h)$	MC; comp. with NDL exp. data.
GT58	Oberhofer, Springer	60	[Munich, Ger.]	0.2–5.0	PMD	C, Fe, Zr, W, Pb, U, H_2O, baryte concr.	FS	½- and 1/10-value layers.	Approx. formulas.
GT59	O'Brien, Lowder, Solon	58	NYO-HS	0.28–10.0	PTI, UVD	H_2O, Fe, Pb	IM; Sph	*BF*	Appl. to UVD distrib.; *BF* rep. as $(1+\alpha t)^{\beta}$.
GT60	Penny	58	ORNL	Unspecif. monoenergetic	PTI, PMD	Unspecif.	IM	$I(r)$	MC.
GT61	Plesch	58	[Karlsruhe, Ger.]	0.5–4.0	PTI	Fe, Pb	FS	$I(r)$	Approx. formulas
GT62	Strobel	61	WAPD	0.5–10.0	PTI	Al, Sn, Pb, U	IM	*BF*	2-exponential fit to GT20.
GT63	Trubey, Penny, Emmett.	62	ORNL	Unspecif. monoenergetic	PLI, PLS, PLC	Input data tapes for 32 elements from H to U.	Lay	$I(r)$	MC.
GT64	Vernon	57	NAA	1.0–10.0	PTI	Magnetite concrete	IM	$I(r)$, *BF*	Quadratic *BF* rep.
GT65	Baumgardt, Trampus, MacDonald	61	APEX	12.0	PMD	Air	IM	$I(r, \rho)$	MC.

TABLE 2. *Gamma-ray penetration experiments (GE)*

Ref.	Author	Yr	Lab. or [place]	Source energy, Mev	Source type	Medium	Absorber configuration	Type of information	Method
GE1	Beach et al.	53	NRL	Cs^{137} (0.66)	PLN, PTI	H_2O	IM	$I(E, r)$	NaI
GE2	Beach, Faust	55	NRL	Na^{24} (2.76)	PTI	H_2O, Hg	IM	$I(r)$	Anthr.
GE3	Broder, Kayurin, Kutuzov.	62	[USSR]	Co^{60} (1.17, 1.33)	PTI	Al, Fe, Pb, Polyethylene.	Lay	$I(r)$	Plastic scint.
GE4	Bulatov	59	[USSR]	Co^{60}, Cs^{137}, Cr^{51} (0.32)	PTI	C, Al, Fe, Pb	SIM	$R(\theta)$	Ion.
GE5	Bulatov, Garusov	58	[USSR]	Co^{60}, Au^{198} (0.41)	PMD	C, Al, Fe, Cd, Pb, Mg, Cu, Hg, Bi, U, H_2O, brass, wood, brick, plexiglass	FS, SIM	$R(\theta)$, SIM $R(r)$, FS $R(Z)$, SIM	Film; ion
GE6	Burton	57, 59	NARF	Co^{60}	PTI	Air, ground	2 media with interface.	$I(E, r, \theta, h)$	NaI
GE7	Clarke, Richards	57	TOI	Na^{24}, Co^{60}, Au^{198}	PTI	Air, H_2O	2 media with interface.	$I(r)$	NaI
GE8	Clifford et al.	60	DRCL	Cs^{137}	PTI	Air-clay, polystyrene-concr; polystyrene-lead.	2 media with interface.	$I(r)$, $I(\theta)$	NaI
GE9	Dahlstrom, Thompson.	62	NRDL	Co^{60}, Cs^{137}	PLS	Al, Fe	FS	$I(r, \theta)$	NaI
GE10	Davis, Reinhardt	57	ORNL	Co^{60}, Cs^{137}, Au^{198}, Ra, Fallout spectr.	PTI, PLI	Air-ground	2 media with interface.	$I(r)$	NaI
GE11	Ebert	61	[Göttingen]	Co^{60}, Cs^{137}, bremss.: E_{max} =0.15 to 0.26.	PTI, PLN	Pb, baryte concr.	FS	$I(r)$	NaI
GE12	Elliot et al.	52	NRL	Co^{60}	PTI	Pb	IM	$I(r)$; *BF*	Film
GE13	Faust	50	NRL	Co^{60}	PTI, PLI	H_2O	IM	$I(E, r)$	Geig.; estim. of spectra by Pb filtration
GE14	Faust, Johnson	49	NRL	Co^{60}	UVD	H_2O	IM	$I(E)$	Geig.
GE15	Garrett, Whyte	54	NRC [Ottawa].	Co^{60}	PTI	Pb, Fe	IM	$I(r)$	Ion.
GE16	Gol'bek, Matveev, Sokolov.	60	[USSR]	Zn^{65} (1.12), Ra, MsTh.	PTI	Sand-air	2 media with interface.	$I(E, r)$	NaI
GE17	Gorshkov, Kodyukov.	58	[USSR]	Na^{24}, Au^{198}	PTI, UVD	H_2O	IM	$I(r)$	Ion.
GE18	Hayward	52	NBS	Co^{60}	PTI	H_2O	IM	$I(E, r)$	Anthr.
GE19	Hayward, Hubbell	54	NBS	Co 60	PMD	Wood, Fe	SIM	$R(E,\theta)$	NaI.
GE20	Hettinger, Starfelt	59	[Lund, Sweden]	Filtered bremss.: E_{max}=0.10, 0.17, 0.25	PLN	H_2O	SIM	$I(E,r,\theta)$	NaI.
GE21	Hubbell, Hayward, Titus	57	NBS	Bremss.: E_{max}=8, 10	PLN	Pb	FS	$I(E,r,\theta)$	NaI.
GE22	Hyodo	62	[Japan]	Co^{60}, Cs^{137}	PTI	Paraffin, Al, Fe, Sn, Pb	SIM	$R(E,\theta)$	NaI.
GE23	Ishimatsu	62	[Japan]	Co^{60}	PTI	H_2O	IM	$I(E,r)$	NaI.
GE24	Jones, A.R.	61	[Chalk River, Can]	I^{131} (0.36) Cs^{137}, Co^{60}	PTI PTI PLI	Air-ground	2 media with interface	$I(r)$	NaI; PLI by integration o PTI.
GE25	Jones, B.L., Harris, Kunkel	55	NARF	Co^{60}	PTI	Air-ground	2 media with interface	$I(r,h)$	Anthr.
GE26	Kazanskii	60	[USSR]	Co^{60}	PTI	H_2O, Fe	SIM	$I(E,r,\theta)$	CsI.
GE27	Kazanskii Belov, Matusevich	58	[USSR]	Co^{60}, Au^{198}	PTI	Fe, Pb	SIM	$I(E,r,\theta)$	CsI.
GE28	Keller, Gonzalez	57	NARF	Co^{60}	PTI	Air	IM	$I(E,r,\theta)$	NaI; comp. with single-scatt. approx.
GE29	Kimel	61	[USSR]	Co^{60}	PLN	Pb–Al, Al-Pb, Pb-Fe, Fe-Pb, Fe-Al, Al-Fe	Lay	*BF*; effect of high or low *Z* abs. nearest source	Geig.
GE30	Kimel, Leipunskii	62	[USSR]	CS^{137}	PMD	H_2O	IM	$I(r,\rho)$	Anthr.
GE31	Kirn, Kennedy, Wyckoff	54	NBS	Co^{60}, Cs^{137} Au^{198}	PLS PLN	Pb, concrete, polyethylene	FS	$I(r)$	Ion.
GE32	Kodyukov	59	[USSR]	Au^{198}, Cs^{137} Zn^{65}, Na^{24}	PTI	H_2O	FS, SIM	$I(r)$	Ion.
GE33	Kukhtevich, Shemetenko	62	[USSR]	Au^{198} Co 60, Na^{24}	PMD	H_2O	IM	$I(r,\theta)$	Anthr.
GE34	Kukhtevich, Shemetenko, Synitsyn	60	[USSR]	Co^{60}	PTI	Med. I: H_2O Med. II: Air, Pb, Ni, Al	2 media with interface	$\frac{I(r)\text{ meas.}}{I(r)\text{ inf.med.}}$	Anthr.
GE35	Kukhtevich, Tsypin, Shemetenko	58	[USSR]	Co^{60}	PTI	H_2O	IM	$I(r,\theta)$	Anthr.
GE36	Kusik et al.	57	MIT	Co^{60}	PTI	Pb, Fe, Pb-Fe sandwich	FS, Lay	$I(r)$	Ion.
GE37	Larichev	61	[USSR]	Co^{60}	PLN	Fe	FS	$I(E,r,\theta)$	NaI.
GF38	Leipunskii, Sakharov	59	[USSR]	Co^{60}	PTI, PLI disk	Air-ground	2 media with interface	$I(r)$	Ion.; PLI disk by integration of PTI.
GE39	Mahmoud	57	[Egypt]	Au^{198}, Cs^{137}, Co^{60}, Na 24	PTI	C, Fe, Pb, H_2O, Concrete	FS	$I(E, r)$	NaI.
GE40	Matveev, Sokolov, Shlyapnikov	56	[USSR]	Cr^{51}, Zn^{65}	PTI	Sand	IM	$I(E, r)$	CsI.

TABLE 2. *Gamma-ray penetration experiments (GE)*—Continued

Ref.	Author	Yr	Lab. or [place]	Source energy, Mev	Source type	Medium	Absorber configuration	Type of information	Method
GE41	Mehlhorn et al.	62	TOI	Co^{60}	PLS	Fe	FS	$I(r)$; solid angle dependence	Ion.
GE42	Mitchell, Smith	58	APEX	Co^{60}	PTI	H_2O-air	2 media with interferface	$I(r)$	NaI; comp. with MC calc. GT 7.
GE43	Peelle, Maienschein, Love	56	ORNL	Co^{60}	PTI	H_2O	IM	$I(E, r, \theta)$	NaI: 2-crystal spectrometer.
GE44	Rexroad, Schmoke	60	NDL	Co^{60}, Cs^{137}	PLI	Air-ground	2 media with interface	$I(r)$	Ion.
GE45	Ritz	58	NBS	Ir^{192}(0.32, 0.47, 2.2, etc.)	PLN	Fe, Pb, concrete	FS	$I(r)$	Ion.
GE46	Rizzo, Galanter	61	BNL	Co^{60}	PLI	H_2O	SIM	$I(r)$	Ion.
GE47	Roys, Shure, Taylor	54	WAPD	N^{16} (6.2)	PTI	H_2O	IM	$I(r)$	Anthr.
GE48	Sakharov	57	[USSR]	Au^{198}, Co^{60}, Na^{24}	PTI, UVD	H_2O	IM, SIM	$I(r)$	Ion.; UVD by integration of PTI.
GE49	Scofield, Lynn, Kreger	58	NRDL	Co^{60}, CS^{137}	PLN; PLS: Co^{60}, Fe; PLI: Co^{60}	Al, Fe	FS	$I(E, r, \theta)$ T(dose) R(dose)	NaI: pulse-ht. distrib.; Ion.
GE50	Scofield, Haggmark	60	NRDL	Co^{60}, Cs^{137}	PLN; PLS: Co^{60}, Fe	Al, Fe	FS	$I(E, r, \theta)$	NaI: photon number flux.
GE51	Soole	55	NPL	Co^{60}	PTI	Air	IM 2 media with interface	$I(r)$	Ion.
GE52	Stokes, Burton	57	NARF	Co^{60}	PTI	Air	IM	$I(E, \theta)$	NaI.
GE53	Titus	58	NBS	Co^{60}	PTI	Steel—steel wool	2 media with interface	$I(r)$; Bndry. eff.	Anthr.; pulse integrator.
GE54	Titus	57 58	NBS	"Plumbob" fallout	PLI	Concrete	FS, IM	$I(r)$	Geig.
GE55	Weiss, Bernstein	53	BNL	Co^{60}, Hg^{203} (0.27)	PTI	H_2O	IM	$I(E,r)$	NaI.
GE56	White	50	NBS	Co^{60}	PTI	H_2O	IM	$I(r)$	Ion.; geig.
GE57	Whyte	55	NRC [Ottawa]	Co^{60}	PTI	Concrete	IM	$I(E,r,\theta)$	NaI.
GE58	Zendle et al.	56	NBS	Bremss.: E_{max}=11 to 37	PLN PMD	H_2O	SIM	$I(r)$	Anthr.; ion.
GE59	Bjärngard, Hettinger	62	[Lund, Sweden]	Bremss.: E_{max}=0.05–0.25.	PMD	H_2O	FS	$I(E,r,\theta)$	NaI telescope.
GE60	Bruce, Pearson	62	[Toronto]	Cs^{137}	PLN	H_2O	SIM	$I(E,r)$	NaI telescope; Integr. over angle.
GE61	Dixon	58	NRC Ottawa	Cs^{137}	PTI	Concrete	SIM; Source embedded.	$I(E,r,\theta)$ outside medium	NaI telescope.
GE62	Futtermenger, Glubrecht, Schultz	62	[Hanover, Ger.]	Fission spectrum filtered by 45 and 90 cm paraffin.	PMD	Pb; ordinary, baryte concrete	FS	$I(E,r)$	Ion.; NaI
GE63	Hashmi	63	[Munich, Ger.]	Hg^{203}, Au^{198}, Cu^{64} (0.51), Co^{60}, K^{42} (1.53), Sc^{46} (1.0 av.), Mn^{56} (1.95 av.), Na^{24}.	PTI	H_2O	IM	$I(r)$, BF	Ion.
GE64	Hyodo, Shimizu	61	[Japan]	Cs^{137}, Co^{60}	PTI	Paraffin, Al, Fe, Sn, Pb	SIM, FS	$R(\rho)$	NaI telescope.
GE65	Mahmoud, El Nady	60	[Egypt]	0.66–1.25	PLN	Concrete	SIM	R	NaI.
GE66	Mitchell	61	APEX	Cs^{137}, Co^{60}	PTI	H_2O, Sn, Fe	IM(H_2O, Sn), FS(Fe)	BF	NaI.
GE67	Mochizuki et al.	62	[Japan]	Co^{60}	PMD	H_2O, Fe, Pb	FS, Lay	BF; effect of high or low Z abs. nearest source.	Ion.
GE68	Sybesma	63	[Leiden, Neth.]	Cs^{137}	UVD	H_2O	Cyl	$I(E)$	NaI.
GE69	Tsypin, Kukhtevich, Kazanskii	56	[USSR]	Au^{198}, Co^{60}, Na^{24}	PTI, PMD	H_2O, Fe, Pb	IM, FS, Lay (Pb-Fe)	$I(r)$	Ion.
GE70	Vasilev, Shishkina	58	[USSR]	Cs^{137}, Co^{60}	PTI	Al	FS	$R(r)$	NaI.
GE71	Leipunski, Kimel, Panchenko	63	[USSR]	Cs^{137}, Co^{60}	PMD	Fe	IM	BF, $I(r,\rho)$	Geig.

TABLE 3. *Neutron penetration theory (NT)*

Ref.	Author	Yr	Lab. or [place]	Source energy, Mev	Source type	Medium	Absorber configuration	Type of information	Method
NT1	Albert, Welton	50	WAPD	Fission	PTI	H_2O, H_2O-Pb H_2O-Fe	IM	$I(r)$	Assumed: first scatter by H is absorption.
NT2	Anthony, Omoda	62	AFSWC	Fission (detonation)	PTI	Air	IM	$I(E, r)$	MC.
NT3	Berger, Cooper	59	NBS	0.3, 1, 3, 6, 9, 14	PLS	H_2O	SIM, FS	$R(E, \theta)$	MC.
NT4	Bethe, Tonks, Hurwitz	50	KAPL	Unspecified monoenergetic	PTI	$A=9$ (Be), $A=\infty$	IM	Slowing down density	CECS; Fourier transform.
NT5	Biggers, Brown, Kohr	60	LA	Fission (detonation)	PTI	Air-ground	2 media with interface	$I(E, r)$	MC.
NT6	Burrell, Cribbs	60	[Lockheed]	5 energies	PLS	Fe	FS	$T(r, \theta)$ $R(r, \theta)$	MC.
NT7	Certaine, Aronson	54	NDA	Fission	PTI	H_2O	IM	$I(r)$ at indium res.	MM.
NT8	Certaine, Goldstein	57	NDA	14.0	PTI	H_2O	IM	$I(r)$	MM.
NT9	Drummond	54	UCRL	Unspecif. monoenergetic	PLN	Unspecif. moderating material	FS, SIM	$R(E, r)$	AT; Laplace transform.
NT10	Faulkner	54	ORNL	Unspecif. monoenergetic	PTI	Air-ground	2 media with interface	$I(\rho, h)$	Assumed: isotropic single scatt.
NT11	Feix, Valentin	56	[France]	Unspecified monoenergetic	PLN	Unspecified	FS	$I(r)$, R	CECS: matrix soln. of diff. eq.
NT12	Foderaro, Obenshain	55	WAPD	0.89	PLI	H_2O	IM, FS	$I(r)$, R	MC; MM.
NT13	French	62	NARF	Fission	PTI	Air	IM	$I(r, \theta)$	MC.
NT14	Holland, Richards	55	TOI	0.025 *ev*; 0.001, 0.1, 0.5, 1, 2, 5, 14 Mev	PTI, PLI	Air	IM	$I(E, r)$	MM.
NT15	Holland, Richards	56	TOI	0.001, 0.1, 0.5, 1, 2, 5, 14	PTI	Air	IM	$I(E, r)$	MM.
NT16	Holland	58	TOI	0.001	PTI	Air	IM	$I(E, r)$	Semi-asymptotic.
NT17	Holte	54	[Uppsala, Sweden]	0.1, 0.5, 1,2	PTI	C, H_2O	IM	$I(r)$	CECS; Fourier transform.
NT18	Kalos	59	NDA	8	PLS	H	FS	$I(E, r)$	MC; IS.
NT19	Keller, Zerby, Hilgeman	58	ORNL	0.55, 1.2, 2, 3, 5	PMD	Air	IM	$I(r, \theta)$	MC: isotropic scattering.
NT20	Kinney	62	ORNL	1–19	PTI	SiO_2 (ground)-Air	2 media with interface	$I(r)$	MC.
NT21	Krumbein	58	NDA	Fission; 2, 4, 6, 8, 10, 14	PTI, PLI	Be, C, H_2O, H_2; several hydrocarbons	IM	$I(E, r)$	MM.
NT22	MacDonald, Baumgardt, Trampus	60	APEX	Monoenergetic	PMD	Air	IM	$I(E, r, \theta)$	First collision analytic, higher orders MC.
NT23	Marcum	60	RAND	3, 14	PTI	Air-ground	2 media with interface	$I(E, r)$	MC.
NT24	Mehl	58	SANDIA	0.1–6.0	PTI	Air	IM	$I(E, r, \theta)$	MC.
NT25	Morgan	59	NOL	Monoenergetic	PLN	H_2O	SIM	R	MC.
NT26	Murray	53	ORNL	Fast neutrons	PTI, PLI	13 elements from H to U	IM	$I(r)$	Laplace transform.
NT27	Obenshain, Eddy, Kuehn	57	WAPD	1, 2, . . . 10	PLN, PLS PLI	H_2O	FS	$I(r)$	MC.
NT28	Podgor	50	ORNL	Fast neutrons	PLN	H_2O	SIM	$I(E)$	All collisions assumed absorption.
NT29	Schiff	55	WAPD	Fission neutrons and gammas	PLN	H_2O-Fe	Lay	$I(E)$, $I(r)$	Integral network.
NT30	Shelton	60	KAMAN	1.0 ev–5.0 Mev	PTI	Air	IM	$I(r)$	Combines theor. data of NT 14, NT 24.
NT31	Spielberg	61	NDA	Fission	PTI	Air	IM	$I(E, r)$	MM.
NT32	Spielberg, Duneer	58	AN	0.025 ev; 0.5, 2.5, 7.5, 10, 14 Mev	PLS	Concrete; soil with varying water content	SIM	$I(r)$	Multigroup diffusion.
NT33	Spinney	55	AERE	Fission	PTI	Concrete	IM	$I(r)$	Transport cross section; AT.
NT34	Stern	53	ORNL	3.0	PTI	H_2O	SIM	R	Isotropic scatt.; analyt. soln.
NT35	Stuart	56	HW	Fast neutrons	Line source	Slightly absorbing moderator	IM	$I(r)$	AT.
NT36	Tait, Biram	53	AERE	Monoenergetic	PLN	Hydrogenous	SIM	$I(E)$	P_1 approx.: $\sigma=\sigma_0 V_0/V$.
NT37	Thompson, Ferguson, Mather	60	NRDL	1/E-shape spectrum: 1 ev $\leq E \leq$ 1Mev	PTI	Air-soil	2 media with interface	$I(r)$, thermal	MC.
NT38	Verde, Wick	47	[Rome, Italy]	D+D, D+B reactions	PTI	~ H_2O paraffin	IM	$I(r)$	Fourier transf.; const. velocity.
NT39	Wells	60	NARF	0.33, 1.1, 2.7, 4, 6, 8, 10.9, 14	PTI, PMD	Air	IM	$I(E, r, \theta)$	MC
NT40	Wick	49	UCRL	0.5, 1, 2	PTI, PLI	H, C	IM	$I(r)$	Laplace transf.
NT41	Wigner, Young	47	CL	Fission	PTI	H_2O	IM	$I(r)$	Assumed: energy loss but no deflection by H collision; compar. with H abs.
NT42	Zerby	57	ORNL	Monoenergetic	PMD	Air	IM	$I(r)$: tissue dose-rate.	MC: CD; integr. of Boltzmann eq.
NT43	Zweifel, Bigelow	55	KAPL	Fission	e^{ikx}	H_2O; H_2O-metals	IM	Age; slowing down density.	B_1, P_1, SG approximations.
NT44	Allen, Futterer, Wright.	62	BRL	0.5, 1, 2, 3, 5, 14	PLS	H_2O, borated polyethylene, Fe, concrete, Nevada test site soil.	FS; Lay	$I(r)$	MC.

TABLE 3. *Neutron penetration theory (NT)*—Continued

Ref.	Author	Yr	Lab. or [place]	Source energy, Mev	Source type	Medium	Absorber configuration	Type of information	Method
NT45	Allen, Futterer, Wright.	63	BRL	0.1, 0.25, 0.5, 1.0, 2, 3, 5, 14.	PLS	Concrete	FS, SIM	R, T, $I(r)$	MC.
NT46	Allen, Futterer, Wright.	63	BRL	0.1, 0.25, 0.5, 1.0, 2, 3, 5, 14.	PLS	Nevada test site soil.	FS, SIM	R, T, $I(r)$	MC.
NT47	Allen, Futterer, Wright.	63	BRL	0.1, 0.25, 0.5, 1.0, 2, 3, 5, 14.	PLS	Fe	FS, SIM	R, T, $I(r)$	MC.
NT48	Avery	62	AEEW	Fission	UVD Sph.	Fe-H_2O	Lay	$I(r)$	Multigroup diffusion.
NT49	Bendall	62	AEEW	1-18	PLN	Unspecif.	IM	$I(r)$	Multigroup diffusion.
NT50	Sleeper	52	ORNL	Fission	PLN	H_2O	IM	BF	Comp. of ANP, NDA calcs.
NT51	Fessler, Wohl	61	NASA	6.0	PTI	H_2O	IM	$I(E,r)$	MC.
NT52	Jones, R. D.	62	WADC	Unspecif. monoenergetic.	PTI, UVD	Unspecif.	FS, Sph, Cyl.	$I(r)$	One-group diffusion; power-series solution.
NT53	Peterson, Williams.	62	BRL	Fission	PTI	Air	IM	$I(r,\theta)$, dose	MM; modified for fast conv. at $\theta=0°$.
NT54	Ptitsyn	61	[USSR]	2.5	PTI	H_2, H_2O	IM	$I(r)$	MM.
NT55	Roberts	59	APEX	10.0	PTI	BeO	FS	$I(r)$	Comp. of 4 solutions of transport eq; comp. with exp. data.
NT56	Sinitsyn, Tsypin	62	[USSR]	0.5—15	PTI	H; mixture of H and heavy component.	IM	$I(r)$	Use of removal cross section data.
NT57	Trubey, Penny	62	ORNL	Fission	PTI	H_2O	IM	$I(r)$ thermal	"Transfusion": comb. of transport and diffusion theory.

TABLE 4. *Neutron penetration experiments (NE)*

Ref.	Author	Yr	Lab. or [place]	Source energy, Mev	Source type	Medium	Absorber configuration	Type of information	Method
NE1	Babb, De Wames	59	NARF	Po-Be (fast) also Co^{60} γ's	PTI	H_2O-Air	2 media with interface	$I(r)$: fast, thermal; gamma flux	Hurst dosim. (fast), BF_3 ctrs. (therm.), anthr. (gammas).
NE2	Baer	53	WAPD	Po-Be	PTI	H_2O-Zr	IM	$I(r)$ therm.	Foils.
NE3	Barr, Hurst	54	ORNL	Po-Be	PLN	~ Tissue	FS	$I(r)$	Proportional counter.
NE4	Bina	60	WADC	Po-Be	PTI	Fe, Al, Pb	Sph.; hemisph.	$I(r)$	Hurst-type tissue-equiv. det.
NE5	Blizard	52	ORNL	Fission	Disk	H_2O-Fe	SIM, FS	$I(r)$ therm., $I(r)$ gammas.	BF_3 ctr., ion.
NE6	Blizard, Miller	58	ORNL	Fission: fast neutrons.	PLI disk	H_2O; Concrete	FS	$I(r)$	Hurst dosim.
NE7	Capron, Crevecoeur.	53	[Belgium]	Ra-Be	PTI	C 60% H 8% O 32%	SIM	$I(\theta)$	Ag foils.
NE8	Caswell et al.	57	NBS	14.1	PTI	H_2O	IM	$I(r)$ therm., In res., fast.	B^{10} lined ctr., In foils, Hurst dosim.
NE9	Chapman, Storrs	55	ORNL	Fission	Disk ~ PTI.	15 elements from H to U; 10 compounds	FS	$I(r)$ therm., fast	Fission chamber, BF_3 ctr., Hurst dosim.
NE10	Clifford	50	ORNL	Fission	Disk	H_2O	SIM	$I(r)$	Ag, In foils, $B^{10}F_3$ ctrs.
NE11	Cochran, et al.	54	ORNL	Fission	PLI	C (graphite)	FS	$I(r)$, $I(E)$	Fission chamber, $B^{10}F_3$ ctrs.
NE12	Cure, Hurst	54	ORNL	Po^{210}—B~2.6	PTI	Concrete	SIM	R (dose)	Proport. ctr., pulse integrator.
NE13	Dacey, Paine, Goodman	49	MIT	Ra-Be	PTI	Air, H_2O, Pb, Fe, W, plus 7 compounds	Sph.	$I(r)$ therm., In res.	Foils.
NE14	Delano, Goodman	50	MIT	MIT cyclotron	PLN	Concrete	FS	$I(r)$ fast, thermal	Foils, film.
NE15	Fillmore	54	NAA	Thermal, epithermal, fast	Reactor pedestal	Fe, Al; ordinary and magnetite concrete	FS	$I(r)$	In foils; U^{238}, Np fission chambers.
NE16	Flynn, Chapman	53	ORNL	Fission	PTI	Pb	Sph.	$I(r)$ fast	Hurst dosim.
NE17	Grantham	61	ORNL	Fission	PLI disk	Barytes aggreg.; Barytes concrete	FS	$I(r)$: fast; thermal	Fission chmbr.; BF_3 ctr.; Hurst dosim.
NE18	Grimeland	53	[Norway]	Fission	PMD	B	Cyl.	$I(r)$	Activation of NaI.
NE19	Hill, Roberts, Fitch	55	ORNL	Fission	PTI	H_2O, H_2O-Al	IM	$I(r)$: In res.	In foils.
NE20	Hungerford	52	ORNL	Po-Be; $Co^{60}(\gamma$'s)	PTI	Air—H_2O Air—concrete.	2 media with interface	R, $I(r, h)$	Fast neutron dosim.; ion.
NE21	Johnson, McCammon, Haydon.	51	ORNL	Fission	PTI	H_2O	IM	$I(r)$ therm.	In foils.
NE22	Jones, F. R.	50	HW	Po-Be, Po-B (fast)	PTI	H_2O, paraffin	Cyl	$I(r)$ fast, slow	Proton rec. ctr. (fast); BF_3 (slow).
NE23	Kogan et al.	59	[USSR]	0.025, 0.22, 0.83, 5; reactor beam	PTI PMD	H_2O, paraffin	SIM	$R(E, \theta)$	Mn foils; MnCl soln.; Cd, B, Na & Co filters.
NE24	Langsdorf, Lane, Monahan.	56	ANL	$Li^7(p,n)Be^7$ 0—1.8	PMD	36 elements, 2 compounds, 1 alloy	Thin plates	$I(E, \theta)$	BF_3 proport. counters.

TABLE 4. *Neutron penetration experiments (NE)*—Continued

Ref.	Author	Yr	Lab. or [place]	Source energy, Mev	Source type	Medium	Absorber configuration	Type of information	Method
NE25	Maienschein et al.	55	ORNL	Fission	PTI	H_2O	IM	$I(r)$	Fission chamber, BF_3 ctr., In foils.
NE26	Munn, Pontecorvo	47	NRC [Montreal]	Ra–Be	PTI	H_2O–Bi H_2O–Pb H_2O–Fe	IM	$I(r)$therm., In res.	Dy, In foils.
NE27	Otis	57	ORNL	Fission	PLI	H_2O	FS	$I(r)$	Au foils.
NE28	Rush	48	[Duke Univ.]	Ra–Be	PTI	H_2O	IM	$I(r)$	In foils.
NE29	Salmon	55	AERE	Thermal	PLI	Concrete	SIM	$I(r)$: diffusion length	In foils.
NE30	Shure, Roys	57	WAPD	N^{17}	PTI	H_2O	IM	$I(E, r)$	BF_3 ctr.
NE31	Dunn	57	WADC	Fast neutrons, Po–Be	PTI	Al, Fe, Pb	Sph.	$I(r)$	Hurst dosim.
NE32	Stickley	56	BNL	Slow neutrons	PLN disk	Tissue–equiv. plastic	SIM	$I(r, \rho)$	Au foils.
NE33	Tittman	53	[Schlumberger, Conn.]	Ra–Be	PTI	H_2O	IM	$I(r)$	In foils; BF_3 ctrs.
NE34	Von Dardel	54	[Stockholm]	D–D reaction	PTI	B, H_2O, D_2O, "Hysil" glass	Cyl	$I(E)$	$B^{10}F_3$ ctr.
NE35	Western	62	NARF	Fission	PLN	Polyethylene, plain and borated; $ZrH_{1.95}$; Inconel X, Be, BeO, Fe	FS	$I(E, r)$; Capture gammas	NaI
NE36	Zaitsev, Komochkov, Sychev	62	[USSR]	170, 250, 350, 480, 660	PMD (cyclotron)	3 concretes: Fe content = 0.4%, 41%, 75%	FS	$I(r)$ (>20 mev)	$C^{12}(n,2n)C^{11}$; activity of C^{11}.
NE37	Broder, Kutuzov, Levin	62	[USSR]	2, 4, 6, 8, 10, 14.9	PTI	H, H_2O, O, C	IM	$I(r)$, removal cross section	Fission chamber.
NE38	Dulin et al.	60	[USSR]	Fission	PLN disk	H_2O	SIM	$I(\rho, r)$; data transf. to PLI disk, PTI	BF_3 ctrs.
NE39	Lence, Liguori, Lowery	61	APEX	Fission	PTI	Be, BeO, LiH, Fe, Pb	Large number of shielding configurations.	$I(r)$: fast, Sub–Cd, epi–Cd.	Foils; Comp. with band calc.
NE40	Tsypin	62	[USSR]	0.5, 1, 3, 8	PLN disk	H_2O, Fe, U	SIM	$I(r, \rho)$	BF_3 ctrs.
NE41	Western	62	NARF	Fission	PMD	Borated polyethylene, Pb, Fe	FS	$I(E, r, \theta)$; $R(\rho)$; fast, thermal, epithermal, capture gammas	BF_3 ctrs, foils, NaI.

TABLE 5. *Electron penetration theory (ET)*

Ref.	Author	Yr	Lab. or [place]	Source energy, Mev	Source type	Medium	Absorber configuration	Type of information	Method
ET1	Archard	61	AEI	0.01–0.10	PLN	Si, Cr, Se, Xe	SIM	R	Diffusion; large-angle single elastic scattering.
ET2	Berger	63	NBS	0.125–2.0	PLN, PLS	Al	Foils	T, R	MC.
ET3	Berger	63	NBS	0.0625–2.0	PLN, PLS, PLI	Al, Au	FS, SIM	$I(E, r)$, T, R	MC.
ET4	Blunck	52	[Würzburg]	1–3000	PLN	Pb, O_2, Arbitrary Z	SIM	Range	Integral transforms.
ET5	Boyd, Morris	60	NBS	1.12-, 23.8-hr fission products	PLI, PTI	Air	IM	$I(E, r)$	MM.
ET6	Crew	61	NBS	0.4	PMD	Air	IM	$I(r, \rho, \theta)$	MM.
ET7	Engelmann	61	[München]	P^{32} (Al only), Tl^{204} (Al, Ag, Au)	PLI	Al, Ag, Au	FS	T, R	Diffusion.
ET8	McGinnies	59	NBS	0.006438–10.46	UVD	Al, Cu, Sn, Pb, air, H_2O, bone, muscle, polyethylene	IM	$I(E)$	Numerical integration, use of ET17.
ET9	Nelms	56, 58	NBS	0.01–10.0	PMD	28 elements from H to U; air, H_2O, 6 other substances	IM	Energy loss, range	Cont. slowing-down; ion. and excitation.
ET10	Rohrlich, Carlson	54	[Princeton Univ.]	0.102–2.04	PMD	Al, Pb	IM	Range, energy loss	Continuous slowing down.
ET11	Sidei, Higashimura, Kinosita	57	[Kyoto Univ., Japan]	0.514–2.0	PLN	Al	Foils	T, $R(\theta)$	MC.
ET12	Spencer	55	NBS	0.01–10.0	PLN, PTI	Be, Al, Cu, Cd, Au, air, polystyrene	IM	Stopping power, resid. range, $I(r)$	Continuous slowing down approx.
ET13	Spencer	59	NBS	0.025–10	PLN, PTI	C, Al, Cu, Sn, Pb, air, polystyrene	IM	$I(r)$	MM.
ET14	Higashimura	61	[Kyoto, Japan]	2.0	PLN	Al	IM	$I(E, r)$	Segment model electron track.
ET15	Linnenbom	62	NRL	0.1–100		Al, Si, SiO_2		Range, energy loss	Use of mass stopping power data.
ET16	Bödy	62	[Hungary]	0.01–0.10	PLN	Z=4–80	SIM	$R(Z)$	Comparison of diffusion theory with single and multiple scattering.
ET17	Spencer, Fano	54	NBS	2.04, 40.9	UVD	Al, Pb	IM	$I(E)$	Continuous slowing-down.

TABLE 6. *Electron penetration experiments (EE)*

Ref.	Author	Yr	Lab. or [place]	Source energy, Mev	Source type	Medium	Absorber configuration	Type of information	Method
EE1	Aglintsev, Kasatkin	62	[USSR]	S^{35} ($\leq$ 0.167) Y^{91} ($\leq$ 1.55)	PTI	Al	Foils	$I(E)$	Not given.
EE2	Agu, Burdette, Matsukawa	58	[Leicester, England]	0.25–0.75	PMD	Be, Al, Cu, Ag, Au	Foils	$T(r)$	Ion.
EE3	Bialobzheskii, Val'kôv	58	[USSR]	0.8	PLN	Al	Foil stack	$I(r)$; range	Electrometric: foils serve as both absorbers and charge collectors.
EE4	Buys	60	[Gent, Belg.]	P^{32}	PTI	Al	Foils	T, R	Geig.
EE5	Engelmann	61	[München]	P^{32} (Al only) Tl^{204} (Al, Ag, Au)	PLI	Al, Ag, Au		T, R	4π ctr.
EE6	Grün	57	[München]	0.005–0.054	PMD	Air	IM	$I(r)$	Luminescense of air.
EE7	Harigel, Scheer, Schultze	61	[München; Würzburg]	20.4	PMD	Freon (CF_3 Br)	Foils	Range	Bubble chamber.
EE8	Huffman	58	ORNL	0.057, 0.080, 0.104, 0.1265	PMD	Al	Foils	$I(r)$	Ion: triple plate chamber.
EE9	Minder	61	[Bern, Switz.]	10	PLN	H_2O	SIM	$I(r)$	Ion; film; chem. dosim. ($FeSO_4$).
EE10	Oberhofer, Springer	60	[Munich]	19 β-emitters 0.053–3.55	PMD	H_2O, Air, Al, Cu, plexiglass	Foils	T, max. range.	Not given.
EE11	Odeblad, Agren	59	[Stockholm]	Cl^{36} (Al, Sn, Pt, cellophane); C^{14}, P^{32} (Al only)	PTI	Al, Sn, Pt, cellophane	Foils	T	Geig.
EE12	Rothenberg	51	NYO-HS	U β's	PTI	Denim (cotton cloth)	1 and 2 9-oz. layers	T	Ion.
EE13	Seliger	55	NBS	up to 0.960		Al, Ag, Sn, Pb, Au, brass	Foils	$T(r)$	2π ctr.
EE14	Trump, Wright, Clark	50	MIT	2, 3	PLN	Al	Foils	$I(r, \theta)$	Ion.
EE15	Tsvetaeva	60	[USSR]	0.20, 0.60; S^{35}, Ca^{45}, Co^{60}, Sr^{90}	PMD	Al	Foils	$I(r)$	Geig.
EE16	Wright, Trump	62	MIT	1.0–3.5	PLN	Be, Mg, Al, Cu, Zn, Cd, Au, Pb, U	SIM	$R(Z)$	Biased collector.
EE17	Andreen	62	[Gothenberg, Sweden]	0.02–0.10; Sm^{153}	PLN	Al, Cu, Ag, Pb	SIM	$R(Z)$	Image β-spectrometer.
EE18	Andreen, Parker, Slatis	63	[Sweden]	0.01 (electron gun)	PMD	Al, Ag, Au	Foils	$R(E, \theta)$, $T(E, \theta)$	Double focusing β-spectrometer, geig.
EE19	Chhabra	62	ANL	Sr^{90}–Y^{90}: <2.2	PLI disk	Lucite	SIM	$I(r)$	Plastic scint., film.
EE20	Cornish	63	STL	1.43–2.0 (Van de Graaff generator)	PLN	H_2O: liquid and ice	SIM	T, R; $I(r)$ vs temp. −195° C to +20 °C	Glass coloration dosim.
EE21	Daddi, D'Angelo	63	[Pisa, Italy]	0.167–2.25 (7 β emitters)	PTI	Al, Au	Foils	Effective atten. coefs.	Geig.
EE22	Danguy	62	[Brussels]	0.17—1.7	PTI	39 elements, compounds, and alloys	Foils	$R(\theta)$, $R(E, r)$	Geig.
EE23	Ehrenberg, King	63	[Birbeck Coll., London]	0.01—0.08	PMD	Polystyrene, KI, RbI, CsI, $CaWO_4$ $CdWO_4$	SIM	$I(r, \rho)$; comp. with calc. ET13	Luminescence.
EE24	Mori, Taira	61	[Japan]	Sr^{90}	PMD	C, Al, Fe, Pb	FS	$R(r, \theta, Z)$	Geig.

TABLE 7. *Elementary geometries, theory (EGT)*

Ref.	Author	Yr	Lab or [Place]	Rad. type, energy (Mev)	Source type	Medium	Structure, terrain, etc. type	Type of information	Method
EGT1	Berger	54	NBS	γ: Co^{60}	PTI off-gnd.	Air	Foxhole	Dose rate at top, middle, bottom	Use of ang. distr. calc. by MM; assume dir. dep. det.
EGT2	Berger	56	NBS	γ: Co^{60}; 0.66, 1, 4, 10	PTI, PLI	Air, concrete	Slab-covered pit shelter; thick wall; dens. interf.	Relative dose rates; bdry. eff. corr.	MM; MC.
EGT3	Berger, Doggett	53	NBS	γ: 1.0	PLI, UVD	Air	Level gnd; inf. and sph. finite cloud	$I(E)$; dose rate; BF	MM.
EGT4	Berger, Lamkin	58	NBS	γ: 1.0	PLI	Air, concrete	Slab-covered pit shelter, blockhouse, open hole	Dose rate within structures	MM; correction for wall refl. and transm.
EGT5	Blizard	59	ORNL	Unspecified monoenergetic	PLI disk, PTI	Unspecif.	Circular disk source	Transform. of PLI disk data to PTI	Inf. series; extrapolation of data.
EGT6	Blizard	60	ORNL	Unspecified monoenergetic	PLI, PTI	Unspecif.	Circular disk source	Geometrical transformations	Inf. series; simple formulas.
EGT7	Chilton, Saunders	57	NCEL	γ: Co^{60}	PLI	Concrete, earth	Slab and earth-covered underground shelters	Dose rate 3′ above floor center comp. with 3′ above level ground	Not given.

Ref.	Author	Yr	Lab or [Place]	Rad. type, energy (Mev)	Source type	Medium	Structure, terrain, etc. type	Type of information	Method
EGT8	Duncan	59	NAA	γ: time-dependent fission products	UVD	Air	Radioactive cloud: vert. and horiz. funnels	$I(r)$	*BF* approx. as $1+\mu r+(\mu r)^2/7E^{2.4}$
EGT9	Eisenhauer	60	NBS	γ: Co^{60}, 1.12-hr fission, 0.7 Mev	PLI	Concrete	Blockhouse	Dose rate as fn. of roof thickness and depth below ceiling	MM: separation of "barrier" and "geometry" shielding.
EGT10	Fodcraro, Obenshain	55	WAPD	Unspecified monoenergetic	PTI, PLI UVD	Unspecif.	Point, line, disk, slab, truncated cone, cyl., sph. sources	$I(r)$	Exponential atten., analytic and series formulas.
EGT11	Fullwood et al.	56	NDL	γ: 1, 2.76	PLI	Air, ground	Foxhole, level ground	Dose rate vs ht. above gnd.; in bottom of foxhole	Use of inf. plane theory.
EGT12	Hubbell	56	NBS	γ: 0.255, 0.5, 1, 2, 3	PLI, UVD	H_2O	Level ground; circular slab roof; body of water	Dose rate vs ht. above gnd. or water; over center of disk	Use of MM calc. data; *BF* fitted to cubic polynomial in $\mu_0 r$.
EGT13	Hubbell, Bach, Lamkin	60	NBS	γ: 1, 1.25, unspecified monoenergetic	PLI; ang. distr. in sph. harmonics	H_2O; unspecified	Rectangular primary and secondary sources: e.g. thin or thick roof	Dose rate opp. corner of rectangular source	Use of angular harmonics calc. by MM; series soln. for thin roof ($\leq\sim$ 1mfp).
EGT14	Hubbell, Bach, Herbold	61	NBS	γ; neutrons; unspecified monoenergetic	PLI; ang. distr. in sph. harmonics	Unspecified	Circular disk primary and secondary sources.	Dose rate off axis	Use of angular harmonics calc. by MM; series soln. using *BF* data from GT13, EGT12.
EGT15	Hubbell, Bach	62	NBS	γ: Co^{60}; 10 energies from 0.5 to 9.5	PLI	H_2O, Al, Fe, Sn, Pb, W, U	Rectangle, or arbitrary finite plane source	Dose rate as fn. of geometric, atten. and *BF* parameters.	Power series soln. using *BF* data.
EGT16	Kovalev, Popov, Smirennyi	57	[USSR]	Unspec. monoenergetic	PLI	Vacuum	Rectangular primary source	Dose rate as fn. of geometric parameters	Numerical integration; no atten. or *BF*.
EGT17	Krieger	54	RAND	γ: 0.7	PLI	Air	Inf. plane; circular disk; inf. long strip	Dose rate 1 meter above gnd.	Analytical and numerical integrations; unscatt. rad. only.
EGT18	Ksanda, Moskin, Shapiro	56	NRDL	γ: 1.25	PLI	Air-ground	2 media with interface; cleared square area in inf. plane source	Ground-roughness effects	Linear *BF* assumed.
EGT19	LeDoux	59	NCEL	γ, neutrons: initial and delayed "standard" spectra	PLI	Concrete, earth	Level ground, buried shelters: rect. slab roof, hemisph., arch	Protection factors	Analyt., numer. integrations.
EGT20	LeDoux, Donovan	61	NCEL	γ: 1–10	PLI	Concrete	Level ground, buried shelters: horiz. cyl., paraboloid, ellipsoid, slab roof, hemisph.	Geom. effects	Analyt., numer. integrations.
EGT21	Malich, Beach	57	NRL	γ: 1.0	PLI	Concrete	Schematized barracks	Dose rate at various points in structure comp. with 3′ above gnd.	Linear *BF* assumed.
EGT22	Meredith	61	NDL	Unspecified	PLI	Vacuum (∼ Air)	Rectangular primary source	Rad. flux at various points above surface	Numer. integr.; no atten. or *BF*.
EGT23	Minder	46	[Bern, Switz.]	Unspec.	PLI	Vacuum	Rectangular; hollow cyl. sources	Dose rate vs "shape" parameters	Series expansion of integral; no atten. or *BF*.
EGT24	Moote	61	CW	γ: Co^{60}	PLI	Fe—H_2O	Rectangular primary source	Dose rate in H_2O slab vs Fe cladding thickness	Solid angle fraction; linear *BF* assumed.
EGT25	Osanov, Kovalev	59	[USSR]	γ: unspec. monoenergetic	PLI	Unspecif.	Rectangular primary source	Dose rate vs "shape" and "barrier thickness" parameters	Numer. integr.; exponential attenuation; no *BF*.
EGT26	Putz, Broido	57	IER	γ: unspec.	Unspec.	Unspecif.	Generalized shields: tetrahedral, parallelopiped, etc.	Generalized formulae for dose rate computation	Transmission matrix.
EGT27	Schlegel	59	IER	γ: unspec.	PLI	Air; standard roof materials (Ref. G11)	Rectangular roof-sections	Dose rates within structure	Numer. integr., linear *BF* assumed.
EGT28	Sievert	21	[Stockholm]	γ: unspec.	PLI	Unspecif.	Circular disk primary source	Dose rate off-axis vs "shape" and "barrier" parameters	Series soln. in powers of "barrier thickness"; no *BF*.
EGT29	Smith, Storm	54	KAPL	Unspec.	PLI; arb. ang. distrib.	Unspecif.	Circular disk source	Dose rate off-axis	Variety of series solns., dep. on source type.

TABLE 7. *Elementary geometries, theory (EGT)*—Continued

Ref.	Author	Yr	Lab or [Place]	Rad. type, energy (Mev)	Source type	Medium	Structure, terrain, etc. type	Type of information	Method
EGT30	Spencer	62	NBS	γ: 1.12-hr fission; Co^{60}, Cs^{137}	PTI PLI PLS	Air, H_2O, Concrete	Density interface, foxhole, shielded basement, light superstructure, vertical wall, blockhouse, vents, mazes, compartm. structures	Extensive graphical data and formulas for calc. of protection factors	Use of MM, MC calc. results; solid angle fraction.
EGT31	Benfenati	61	[Saluggia Italy]	γ; neutrons; unspecif. monoenergetic	Disk: PLI; Fermi ang. distrib.	Unspecif.	Circular disk primary and secondary sources.	Dose rate on axis	Analytical integrations; unscatt. rad. only.
EGT32	Casper, Carver	58	APEX	γ: fission, 0.5–9.5	PLI disk, radial dependence	Al, Fe, Pb	Fe slab with hole; Al, Fe, Pb plugs	$I(r)$ on plug axis	Analyt. integr.; use of *BF* data.
EGT33	Eisenhauer	63	NBS	γ: Cs^{137}, Co^{60}	PLI	Air, Concrete	Level ground; roof sources; vertical walls, blockhouses, compartm. structures.	Graphical data and formulas for calc. protection factors. Comp. with experim.	Use of MM, MC calc. results; solid angle fraction.
EGT34	Holland, Gold	62	TOI	γ; induced in ground by neutrons with energies: 0.025 ev; 9.89, 14 Mev	PLI (thermal); PLS (fast)	Air, Ground	Level ground	Dose rate in air due to (n, γ) reactions in ground from point neutron source in air.	Vacuum, SIM earth for neutron capture; plane symmetry for γ pen.
EGT35	Leimdörfer	62	AE	γ: 1, 2, 4, 6, 10	PTI	Concrete	Spherical room, PTI source at center.	$R(E, \theta)$ vs radius of room; effect of mult. refl.	MC.
EGT36	Rose	56	ORNL	α-particles	Disk: anisotropic ang. distrib.	Vacuum	Circular disk source.	Det. response on axis; finite disk detector.	Legendre expansion.
EGT37	Yakhontova, Kononenko, Petrov	62	[USSR]	β: unspecif.	PLI disk	Unspecif. multicomponent.	Circular disk source; single and layered medium.	$I(r)$ on axis	Analytical formulas.

TABLE 8. *Elementary geometries, experiments (EGE)*

Ref.	Author	Yr	Lab or [Place]	Rad. type, energy (Mev)	Source type	Medium	Structure, terrain, etc. type	Type of information	Method
EGE1	Auxier et al.	59	ORNL	γ: Co^{60}, Cs^{137}	PLI	Air; standard building materials.	Thin and thick-walled houses; level ground.	Dose rate in houses from sim. fallout field; dose above rectangular source array.	Ion.
EGE2	Batter	61	TOI	γ: Co^{60}	PLI	Fe	Vent protruding from underground shelter.	"In and down" effect.	Ion.
EGE3	Batter, Starbird	61	TOI	γ: Co^{60}	PLI	Concrete	Blockhouse	Dose rate from sim. fallout field	Ion.
EGE4	Batter, Starbird	62	TOI	γ: Co^{60}	PLI	Fe	Compartm. structure	Effect of strip sources	Ion; scale model.
EGE5	Bernstein, Clarens, Weiss	53	BNL	γ: Co^{60}	PTI off-gnd	Air	Foxhole	Dose rate at top, middle and bottom	NaI.
EGE6	Brodeur, Batter	62	TOI	γ: Co^{60}	PTI	Fe	Protruding vent	"In and down" scatt.	Ion.
EGE7	Burson, Borella	61	EGG	γ: Co^{60}	PLI	Earth, corrugated steel.	Earth-covered shelter	Protection factor.	Ion.
EGE8	Clifford	61	DRCL	γ: Cs^{137}	PLI	Air-ground	Foxhole in unif. contam. plane	Dose rate along fox-hole axis and midway to wall; gnd. pen. contrib.	Ion.
EGE9	Clifford	62	DRCL	γ: Cs^{137}	PTI	Sand between plywood; Fe (scale model)	Blockhouse: full-size and 1/10 scale model	Validity of model studies	Ion.
EGE10	Davis, Reinhardt	62	ORNL	γ: Co^{60}, Cs^{137}	PTI	Air-ground	Square array of sources on level gnd.	Dose rate vs ht. above gnd.	NaI, airborne.
EGE11	Davis, Reinhardt	62	ORNL	γ: Co^{60}, Cs^{137}	PTI, PLI	Air-ground	Level ground; extended sources	Dose rate vs ht. above gnd.	NaI.
EGE12	Eisenhauer	59	NBS	γ: Co^{60}	PLI	Wood, concrete	Rectangular and ring sources on level gnd., houses with sources on roof and surr. area	Dose rates over simple source arrays, within houses; wall pen. effects.	Ion.; detailed math. analysis of data.

TABLE 8. *Elementary geometries, experiments (EGE)*—Continued

Ref.	Author	Yr	Lab or [Place]	Rad. type, energy (Mev)	Source type	Medium	Structure, terrain, etc. type	Type of information	Method
EGE13	Goulding, Cowper	53	[Chalk River, Can.]	β: P^{32} (~fission)	PLI	Air-soil	Level ground	Relative importance of fallout β's	Geig., thin-window.
EGE14	Hill	54	RAND	γ: Zr^{95}, Nb^{95} (0.76)	PLI	Air-soil	Streets; categorized structures	Dose rate rel. to 1 m above inf. pl.	Analysis of data assuming single scatt.
EGE15	Huddleston et al.	62	NCEL; EGG	Fallout γ's	PLI	Air-soil	Flat lake-bed; semi-rough terrain; wild desert	$I(r, \theta)$; ground roughness effects.	NaI.
EGE16	Margulis, Khrustalev	57	[USSR]	γ: Co^{60}	PLI	Air	Rectangular source array of 1 m-Co^{60} rods	Dose rate profiles across source; vs. ht. above source	Activated phosphor dosimeters; theor. analysis using circular sector approx.
EGE17	Mather, Johnson, Tomnovec	62	NRDL	γ: 9-day-old fission products	PLI	Air-ground	Level ground	$I(E, r, \theta)$	NaI.
EGE18	Plummer	62	NRDL	γ: Co^{60}	PLI	Air-ground, Fe	Vertical wall	Protection factor vs wall thickness, collimator solid-angle.	NaI.
EGE19	Schlemm, Anthony, Burson	59	AFSWC	γ: Co^{60}	PLI	Air-ground	Foxhole, shielded basement, cleared areas	$I(E, r, \theta)$	NaI.
EGE20	Schlemm, Anthony	59	AFSWC	γ: La^{140}	PLI	Air, ground, concrete	Foxhole, slab covered basement, cleared circular areas	$I(r, \theta)$	Geig.
EGE21	Schmoke, Rexroad	61	NDL	γ: Co^{60}, Cs^{137}	PLI	Plywood, Fe, concrete	Blockhouse	Dose rate in structure vs. position, roof material and thickness	Ion.
EGE22	Schumchyk, Tiller	60	NDL	γ: Co^{60}	PLI	Air-ground	Foxhole	Gnd. pen. (lip contrib.)	Ion.
EGE23	Tomoeda, Hastings, Shumway	60	NRDL	γ: Co^{60}	PTI	Fe	Compartmented structure: scale model	"Geom. factors": meas. dose ÷ unatten. calc. dose	Ion.
EGE24	Clifford	63	DRCL	γ: Cs^{137}	PLI	Air-Concrete	Level slabs with concentric and with parallel sawtooth grooves	Ground roughness effects.	Ion.
EGE25	Donovan, J. L.	61	[U. of Mich. Ann Arbor]	γ: Co^{60}	PLI	H_2O–Fe	Rectangular PLI source for food irradiator.	$I(r)$ vs. Fe cladding thickness.	Ion.
EGE26	Johansson	62	[Lund, Sweden]	γ: 7 Mev for full-scale structure; 2.62 Mev for model	PMD, PTI	Concrete for full-scale structure; Fe for model	FS; straight and 3-legged ducts.	Validity of small-scale models for shielding studies.	NaI.
EGE27	Ferguson	63	NRDL	Fallout γ's	PLI	Air-ground	Desert, dry lake bed, plowed ground.	Ground roughness effects; $I(E, h, \theta)$	NaI; comp. with theor. results in ref. G1–EGT 30.

TABLE 9. *Ducting (D)*

Ref.	Author	Yr	Lab or [Place]	Rad. type, energy (Mev)	Source type	Barrier material	Geometry	Type of information	Method
D1	Barcus	59	SANDIA	n	PTI	Unspecif.	Straight and bent ducts	Generalized expressions	Calc.
D2	Benenson, Fasano	57	WADC	n (fission)	PLI	H_2O	Straight cylindrical ducts.	Effect of "lip" pen.	Exp. using S^{32} (n, p) P^{32} det.; calc. using ray analysis.
D3	Bergelson	61	[USSR]	n (fast)	PLI	H_2O, concrete	Straight cylindrical ducts	Formulas; no data	Age approx.
D4	Chappell	57	KAPL	γ	PLI, PLC, Fermi	Unspecif.	Straight cylindrical duct	Nomogram; approx. formula	Scattering neglected.
D5	Chilton	61	NCEL	γ: 0.34, .5	PTI	Concrete	2-legged rectangular ducts	Effect of off axis detector and source	Calc., albedo approach.
D6	Clifford	62	DRCL	γ: Cs^{137}	PTI	Concrete	Duct with side branches	Spectral, transmission data	Ion.
D7	Eisenhauer	60	NBS	γ: Co^{60}	PTI	Concrete	Bent ducts	Effect of one and two right-angle turns	Ion.
D8	Fisher	56	AVCO	n: unspecif.	PLC	Fe	Straight and bent ducts, annulus, gaps	Effect of bends, offsets; approx. formulas.	One-velocity diffusion theory.
D9	Green	62	NCEL	γ: Co^{60}	PTI	Concrete	2-legged rectangular duct; source, det. on axis.	Dose rate along duct axis.	Exp.; analysis using single scatt. approx.
D10	Horton	59	AERE	n: thermal, fast	PLN	Unspecif.	Helical duct	$I(r)$ along duct vs ratio of duct radius to helix radius	Approx. by successive straight sections joined at const. angle
D11	Horton, Halliday	56	AERE	n: thermal	Fermi plane source	H_2O	Straight, 3-legged cyl. ducts	$I(r)$ along duct axis.	Exp.: foil detectors.

TABLE 9. *Ducting (D)*—Continued

Ref.	Author	Yr	Lab or [Place]	Rad. type, energy (Mev)	Source type	Barrier material	Geometry	Type of information	Method
D12	Horton et al.	56	AERE	n: thermal	Fermi plane source	Concrete, Fe lined	Straight annular duct	$I(r)$ along annulus	Exp.; Mn foils; analysis using duct wall albedo.
D13	Hungerford	59	ORNL	n: uspecif.	PLC	Unspecif.; Na in duct	Bend in pipe carrying scatt. and weakly abs. medium	$I(r)$ on and off duct axis.	Diffusion; soln. in in terms of Bessel fn.
D14	LeDoux, Chilton	61	NCEL	γ: Co^{60}	PTI	Concrete	2-legged rectangular ducts	$I(r)$ along duct axis; corner lip effects.	Calc.; albedo approach.
D15	LeDoux, Chilton	61	NCEL	γ: Co^{60}	PLI, PLC	Concrete	2-legged rectangular ducts; shelter entranceways	$I(r)$ along duct axis.	Calc.; comp. with D7, D27 exp. data.
D16	Mironov	62	[USSR]	n: thermal, fast	PLC	Graphite	Rectangular slot; annular duct	$I(r)$ along duct axis.	Calc.; comp. with exp.
D17	Neuberger, Johnston	57	NARF	n	Arbitr.; PLC		Straight cyl. duct	$I(\rho)$ beyond duct.	Calc.
D18	Novak	57	ASAE	n: thermal, fast	PTI	Graphite	Rectangular and cyl. ducts.	$I(r)$ along duct axis: fast, slow.	2-group diffusion.
D19	Park, Agnihotri, Silverman.	62	[U of Md.]	γ: Co^{60}	PTI	Concrete	Straight, 2-legged rectangular ducts.	$I(r)$ along duct axis; effect of successive scatterings.	Exp.; analysis by detailed MC calc.
D20	Price, Horton, Spinney	57	AERE	n: fast, thermal	PLC	H_2O, concr.; Fe duct-lining.	Straight, bent, annular, etc. ducts.	Collection of formulas and exp. data.	Semi-empirical fits to data.
D21	Rizzo, Quadrado, Eisenhauer	60	BNL	γ: Co^{60}	PTI	Concrete	2- and 3-legged rectangular ducts.	$I(r)$ along duct axis.	Exp.
D22	Rockwell (Reactor Des. Manual).	56	BNL, WAPD etc.	γ's, fast n's from fission.	PLI, PLC, Fermi	H_2O, Pb	Rectangular slots; cylindrical, annular ducts.	Refs. to classified as well as unclassified literature.	Exp.
D23	Roe	52	KAPL	n	PLI	Unspecif.	Cyl. ducts	Formulas, series expansions.	One-velocity diffusion theory.
D24	Shore, Schamberger.	56	BNL	n	PTI	H_2O	Straight cyl. ducts; plane slots.	$I(\rho)$ beyond duct or slot.	Exp.
D25	Simon	55	ORNL	γ; n	PLI	H_2O	Straight and bent ducts.	Formulas	Calc.: albedo analysis.
D26	Simon, Clifford	56	ORNL	n	PLI	H_2O	Long thin air ducts; straight and bent.	Formulas	Single bend of angle θ; series of θ-bends.
D27	Terrell, Jerri, Lyday.	62	ARF	γ: Co^{60}, Cs^{137}	PTI	Concrete	Ducts, shelter entranceways.	Comparison of Z-and U-shapes.	Ion.
D28	Chapman	62	NCEL	γ: Co^{60}	PTI	Concrete	2-legged square duct.	$I(r)$ along duct axis; contrib. of various reflecting surfaces.	NaI; comp. with albedo theor. calc.
D29	Fowler, Dorn	62	NCEL	γ: Co^{60}	PTI	Concrete	2- and 3-legged round ducts.	$I(r)$ along duct axis; comp. with square duct.	Geig.; Ion.; single scatt. analysis.
D30	Piercey, Bendall	62	AEEW	n: fission	PLN	H_2O; air in ducts.	Straight cyl. ducts.	$I(r)$ (fast) up to 200 duct radii along axis.	$S^{32}(n, p)P^{32}$ detector; comp. with moments calc.
D31	Piercey	62	AEEW	n: fission	PLN	H_2O; air in ducts.	Straight cyl. ducts.	$I(r)$ (thermal) up to 200 duct radii along axis.	Foils; comp. with moments calc.
D32	Collins	62	NARF	γ: Co^{60} n: Po-Be	PTI; cos, cos^2, cos^3, point sources.	H_2O; Al lining	Straight cyl. duct	$I(\rho)$ beyond duct.	Anthr., fast-neutron dosim., comp. with MC calc.

TABLE 10. *Realistic structures (RS)*

Ref.	Author	Yr	Lab or [Place]	Rad. type, energy (Mev)	Source type	Barrier material	Structure, terrain, etc. type	Type of information	Method
RS1	Batter, Starbird	61	TOI	γ: Co^{60}	PLI	Concrete; hollow tile blocks; frame roof.	Basement, light superstructure.	Dose rate in basement, sources on gnd.	Ion.
RS2	Batter, Kaplan, Clarke.	60	TOI	γ: Co^{60}, Ir^{192} (0.34)	PTI, PLI	Concrete; brick facing.	Office bldg. [AEC, Germantown Md.]	Dose rates in interior due to roof, gnd. sources.	Ion.
RS3	Borella, Burson, Jacovitch.	61	EGG	γ: Co^{60}	PLI	Concrete; brick facing.	Office bldg. [BNL Med. center]	do.	Ion.
RS4	Burson, Parry, Borella.	62	EGG	γ: Co^{60}	PLI	Stucco and frame.	Southwestern residential home; no basement.	do.	Ion.

TABLE 10. *Realistic structures (RS)*—Continued

Ref.	Author	Yr	Lab or [Place]	Rad. type, energy (Mev)	Source type	Barrier material	Structure, terrain, etc. type	Type of information	Method
RS5	Clarke, Batter, Kaplan.	59	TOI	γ: Co^{60}	PLI	Brick; reinf. concr.; frame.	Multistory bldg. blockhouse, basement, open hole, underground shelter.	Dose rates in interior due to roof, gnd. sources.	Ion.
RS6	Cunningham et al.	57	DRCL	γ: Co^{60}, Cs^{137}	PLI		Residential homes.	Protection factor in basement, first floor.	Ion.
RS7	Graveson	56	NYO–HS	Fallout γ's	PLI: roof, surrounding area	Al	Standard housing structure.	Dose rates within struct. comp. to in open.	NaI.
RS8	Malich, Beach	57	NRL	γ: 0.5–10.0; fission γ's, n's.	PLI, PTI	Concrete, soil.	Barracks, underground shelters.	Total dose rate from prompt radiations.	*BF* fitted to quadratic.
RS9	McDonald	56	[Brit. Home Off.]	γ: Co^{60}	PLI	Brick; frame roof.	Residential home	Protection factor.	Ion.
RS10	Putz, Kuykendall	59	IER	γ: Co^{60}	PLI	Frame; brick; precast concr.	Resid. homes: 1- and 2-story.	Dose rate within structures from sources on roof, surr. area.	Exp.; math. analysis using linear *BF*.
RS11	Rudloff	61	[Germany]	γ: 0.7; 24-hr fission prod.	PLI	Concrete	Buildings with basements.	Contrib. of rad. scatt. in gnd.-floor to basement.	Calc.: geom. factor; linear *BF*.
RS12	Shumway, Tomoeda et al.	60	NRDL	γ: Co^{60}	PLI	Fe	Aircraft carrier, unif. contam. on flight deck.	Dose at various pts. at 3 levels below flt. deck.	Ion.; traveling source.
RS13	Spencer, Eisenhauer.	62	NBS	γ: 1.12 hr fission	PLI	Concrete	Schematized buildings, apertures, offsets, areaways, neighboring roofs, etc. considered.	Protection factor.	Computer program for Nat. Fallout Shelter Survey.
RS14	Starbird, Batter, Mehlhorn.	61	TOI	γ: Co^{60}	PLI	Fe	Scale models of residential-type structures.	Dose rates within structures; comp. with full-scale results.	Ion.
RS15	Strickler, Auxier	60	ORNL	γ: Co^{60}	PLI	Frame; concrete block.	Typical Oak Ridge homes.	Dose rate within structures from sources on roof, surr. area.	Ion.
RS16	Tomoeda, Hastings, Miller.	60	NRDL	γ: Co^{60}, Cs^{137}, Ir^{192}	PTI	Fe	Light aircraft carrier.	Dose rate within ship due to sources on flight deck.	Ion.
RS17	Tomoeda et al.	59	NRDL	γ: Co^{60}, Cs^{137}, Ir^{192}	PLI PTI	Fe	Light aircraft carrier.	Protection factor within ship.	Ion; integr. of PTI data to get PLI.
RS18	Waldorf	59	NRDL	γ	PLI	Fe	Light aircraft carrier.	Comparison of exp. dose-rate data with available theory.	Numerical, analytical integrations.
RS19	Burson	63	EGG	γ: Co^{60}	PLI	Concrete	3 multi-story masonry buildings; ranch-type home with underground shelter.	Dose rate within structures from sources on roof, surr. area.	Ion; NaI.
RS20	LeDoux	63	OCD	γ: 1.12-hr fission	PLI	Concrete	Buildings with windows, interior partitions, basements.	Protection factor.	Schematization as single-story solid-wall equiv. buildings; use of G1, G46, calc. data.

Glossary to Tables

Laboratories

AE Aktiebolaget Atomenergi, Stockholm, Sweden.

AEEW Atomic Energy Establishment, Winfrith, Dorset, England.

AEI Associated Electronic Industries, Ltd., Aldermaston, England.

AERE Atomic Energy Research Establishment, Harwell, Berks., England.

AFSWC Air Force Special Weapons Center, Kirtland AFB, N. Mex.

AFSWP Armed Forces Special Weapons Project, Washington, D.C.

AN Associated Nucleonics, Inc., Garden City, N.Y.

ANL Argonne National Laboratory, Argonne, Ill.

APEX Atomic Products Division, General Electric Co., Cincinnati, Ohio.

ARF Armour Research Foundation, Chicago, Ill.

ASAE	American Standard, Atomic Energy Div., Redwood City, Calif.
AVCO	Avco Advanced Development Div., Stratford, Conn.
BNL	Brookhaven National Laboratory, Upton, L.I., N.Y.
BRL	Ballistic Research Labs., Aberdeen Proving Ground, Md.
CL	Clinton Laboratories, Oak Ridge, Tenn.
CW	Curtiss-Wright Corp., Princeton, N.J.
DRCL	Defence Research Chemical Laboratories, Ottawa, Canada.
EGG	Edgerton, Germeshausen and Grier, Inc., Goleta, Calif.
HW	Hanford Atomic Products Div., General Electric Co., Richland, Wash.
IER	Inst. of Engineering Res., Univ. of Calif., Berkeley, Calif.
KAMAN	Kaman Aircraft Corp., Colorado Springs, Colo.
KAPL	Knolls Atomic Power Lab., General Electric Co., Schenectady, N.Y.
LA	Los Alamos Scientific Lab. (Univ. of Calif.), Los Alamos, New Mexico.
MIT	Mass. Inst. of Technology, Cambridge, Mass.
NAA	North American Aviation, Downey, Calif.
NARF	Nuclear Aircraft Research Facility, Convair, Fort Worth, Tex.
NASA	National Aeronautics and Space Admin., Lewis Res. Center, Cleveland, Ohio.
NBS	National Bureau of Standards, Washington, D.C.
NCEL	U.S. Naval Civil Engineering Lab., Port Hueneme, Calif.
NDA	Nuclear Development Corp. of America, White Plains, N.Y.
NDL	Nuclear Defense Lab., Army Chemical Center, Md.
NOL	U.S. Naval Ordnance Lab., White Oak, Md.
NPL	National Physical Laboratory, Teddington, England.
NRC	Nat. Res. Council, Canada, Ottawa and Montreal.
NRDL	U.S. Naval Radiological Defense Lab., San Francisco, Calif.
NRL	Naval Research Lab., Washington, D.C.
NYO–HS	Health and Safety Div., AEC, New York Office.
OCD	Office of Civil Defense (DOD), Washington, D.C.
ORNL	Oak Ridge National Laboratory, Oak Ridge, Tenn.
RAND	RAND Corp., Santa Monica, Calif.
SANDIA	Sandia Corp., Albuquerque, N. Mex.
STL	Standard Telecommunication Labs., Ltd., Harlow, Essex, England.
TOI	Technical Operations, Inc., Burlington, Mass.
TRG	Technical Research Group, Inc., Syosett, N.Y.
UCRL	University of California Rad. Lab., Berkeley, Calif.
WADC	Wright Air Development Center, Dayton, Ohio.
WAPD	Westinghouse Electric Corp., Atomic Power Div., Pittsburgh, Pa.

Information Type

$I(E)$	Spectra
$I(r)$	Depth dose or integrated intensity
$I(\theta)$	Angular distribution
$I(E, r)$	Depth spectra
$I(E, \theta)$	Spectra: angular dependence
$I(E, r, \theta)$	Spectral-angular distributions
$I(\rho)$	Radial distributions
$I(r, h)$	Lateral-vertical distributions
T	Transmission
R	Reflection (albedo)
BF	Buildup factor

Method

MC	Monte Carlo
MM	Moments method
AA	Analytical absorption
CD	Collision density
IS	Importance sampling
CECS	Constant effective cross section
AT	Age theory
NaI	Sodium iodide crystal spectrometer
CsI	Cesium iodide crystal spectrometer
Anthr	Anthracene crystal spectrometer
Ion	Ionization chamber
Geig	Geiger counter
B_1 aprxmn	Legendre components of the scattering function $B_l=0$ for $l>1$
P_1 aprxmn	Legendre components of the flux $P_l=0$ for $l>1$
SG aprxmn	Selengut-Goertzel approximation

Source Type

PLN	Plane normal
PLS	Plane slant
PLI	Plane isotropic
PLC	Plane cosine
PTI	Point isotropic
PMD	Point monodirectional
UVD	Uniform volume distribution

Absorber Configuration

IM	Infinite medium
SIM	Semi-infinite medium
FS	Finite slab
Sph	Spherical shell
Cyl	Cylindrical shell
Lay	Layers

General References (G)

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